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EP 1329759 A1 **US 6392690 B1**
US 20030052836 A1

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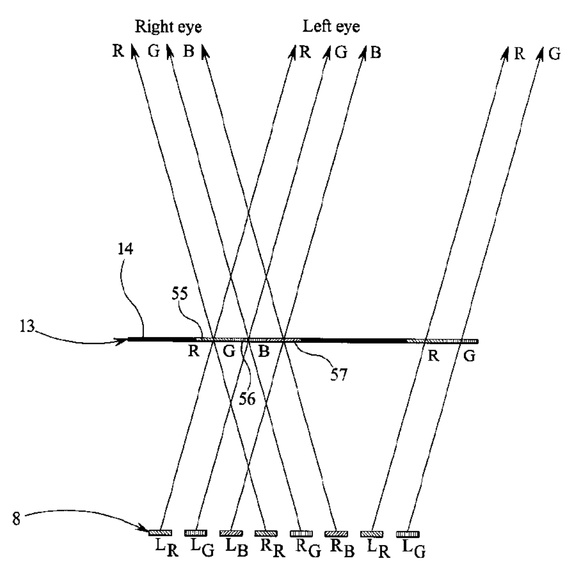
INT CL^7 **G02B, H04N**
Other: **ONLINE DATABASES: WPI, EPODOC, JAPIO**

(54) Abstract Title: **Multiple view directional display with parallax optic having colour filters.**

(57) A directional display, such as an autostereoscopic display or dual view (right and left image) display, comprises an image display device having picture elements 8 and a parallax optic comprising an array of colour filters 13. The colour filters may transmit more than one primary colour and each picture element may emit light of a primary colour. The set of picture elements or pixels 8 may be illuminated by an array of light sources, which may emit light of a secondary colour. The colour filters may be aligned with the picture elements, have opaque 14 or transparent (15, Figure 10) regions for blocking or transmitting light of all three primary colours, be of a secondary colour, and may be arranged in apertures in the parallax optic. A periodically repeating pattern of colour filters may be provided. Filters may be arranged such that a region at 90 degrees or perpendicular to the display appears dark (see region 26 in Figure 7(c)). Filters may overlap - see Figure 17a for example.

FIG 12



GB 2 405 545 A

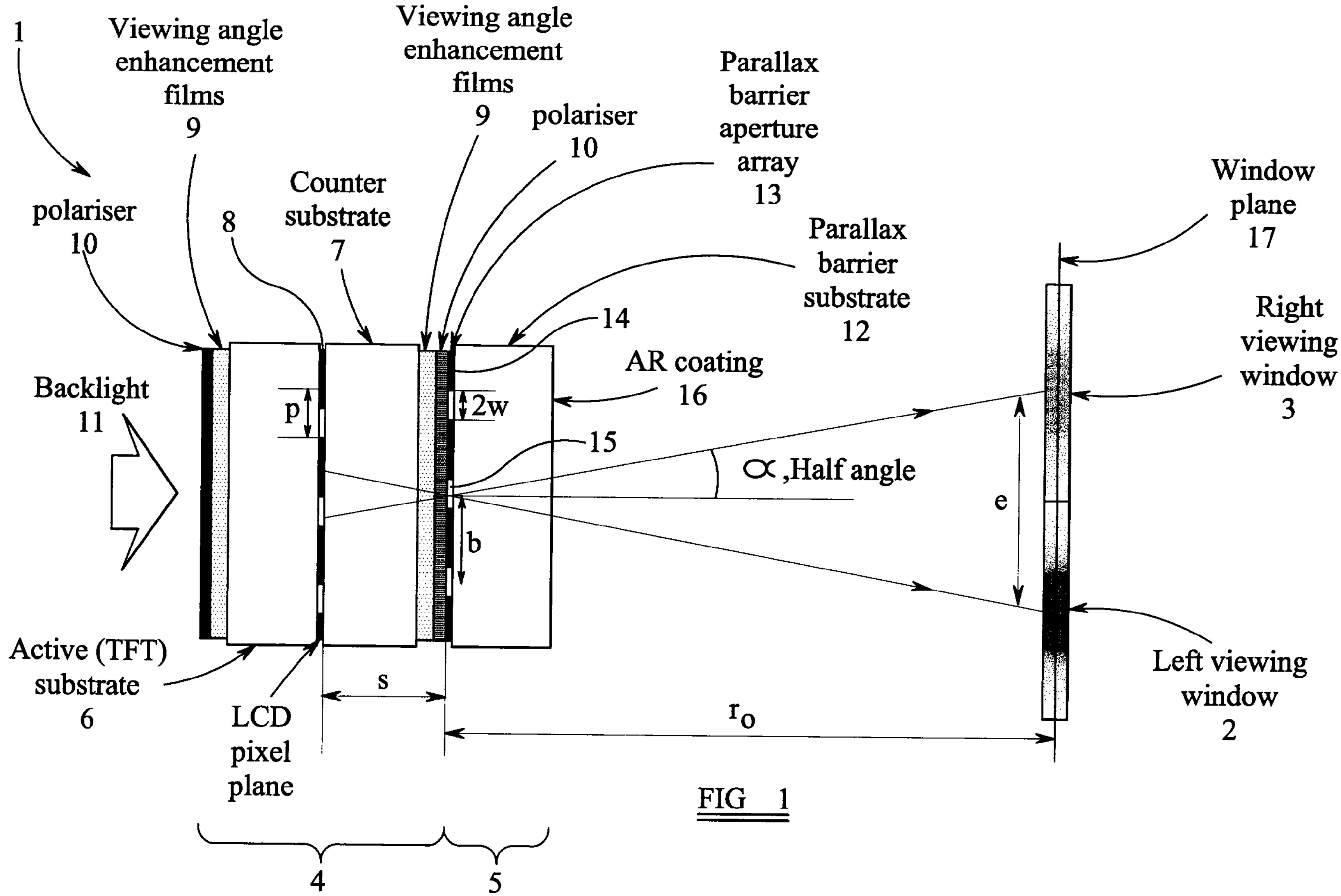

1
Viewing angle enhancement films 9
Viewing angle enhancement films 9
polariser 10
Parallax barrier aperture array 13
Window plane 17
polariser 10
8
Counter substrate 7
Parallax barrier substrate 12
14
Right viewing window 3
AR coating 16
Backlight 11
p
2w
15
∝ ,Half angle
e
b
Active (TFT) substrate 6
s
LCD pixel plane
r_o
Left viewing window 2
4
5

FIG 1

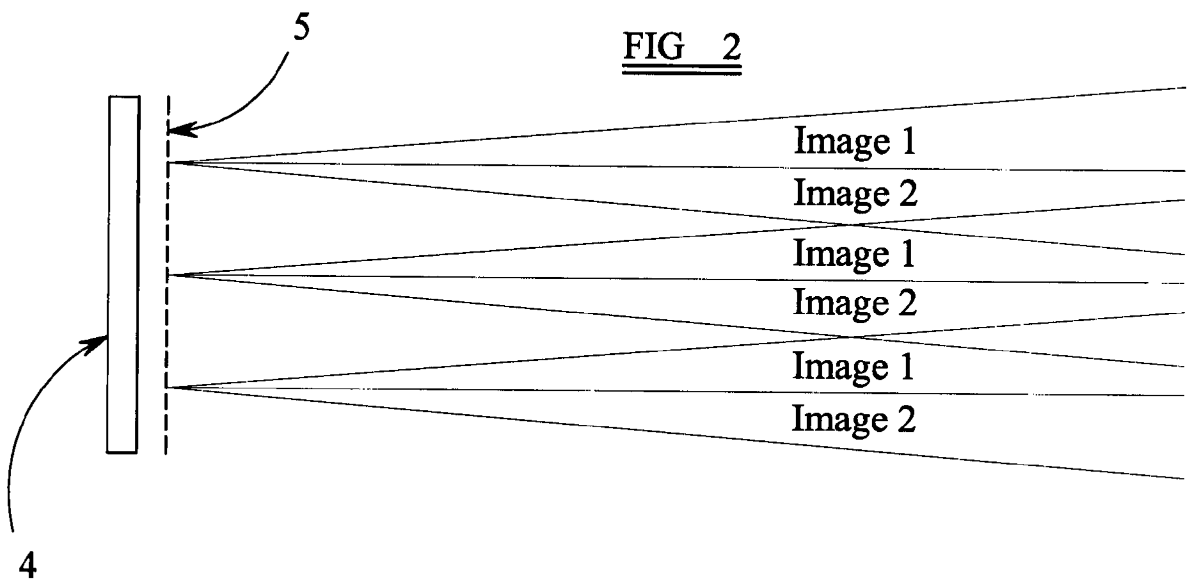

5
Image 1
Image 2
Image 1
Image 2
Image 1
Image 2
4

FIG 2

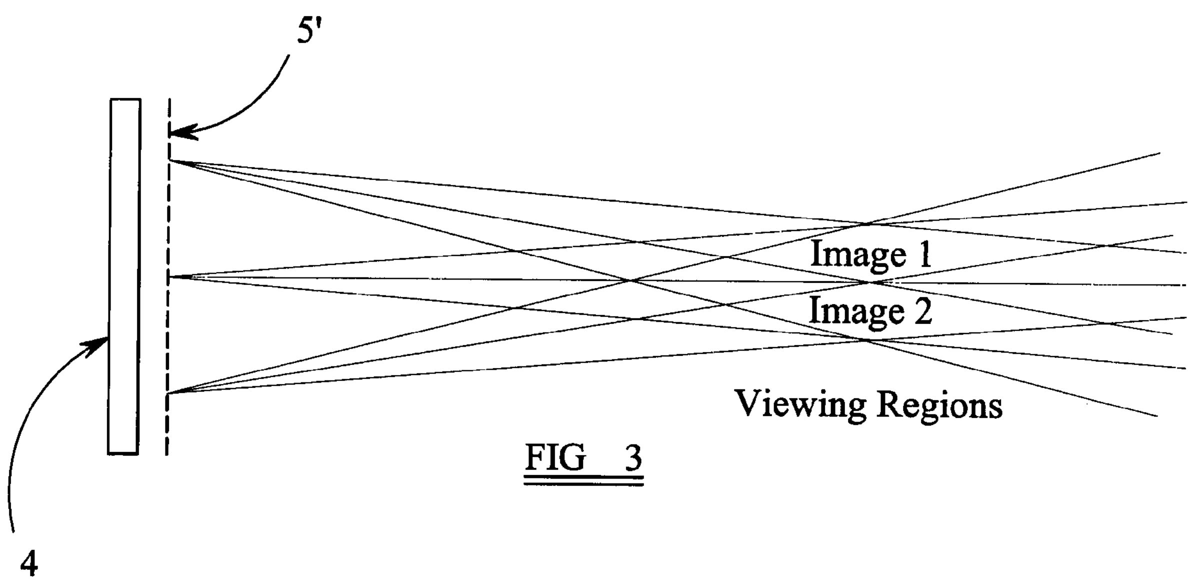

5'
Image 1
Image 2
Viewing Regions
4

FIG 3

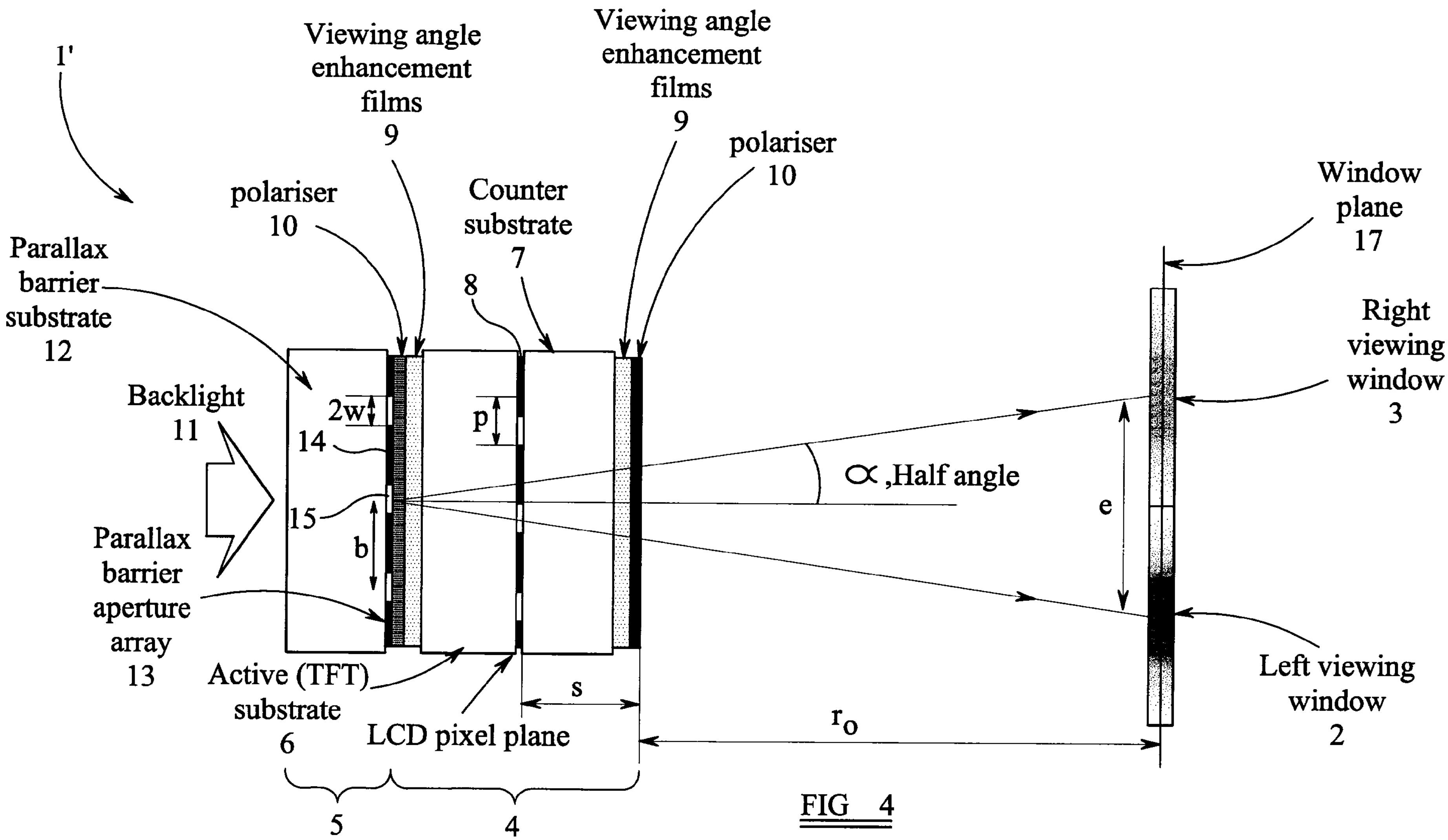

1'
Parallax barrier substrate 12
Backlight 11
Parallax barrier aperture array 13
polariser 10
Viewing angle enhancement films 9
Counter substrate 7
8
Viewing angle enhancement films 9
polariser 10
2w
14
15
b
p
Active (TFT) substrate 6
LCD pixel plane
s
5
4
∝ ,Half angle
e
r_o
Window plane 17
Right viewing window 3
Left viewing window 2

FIG 4

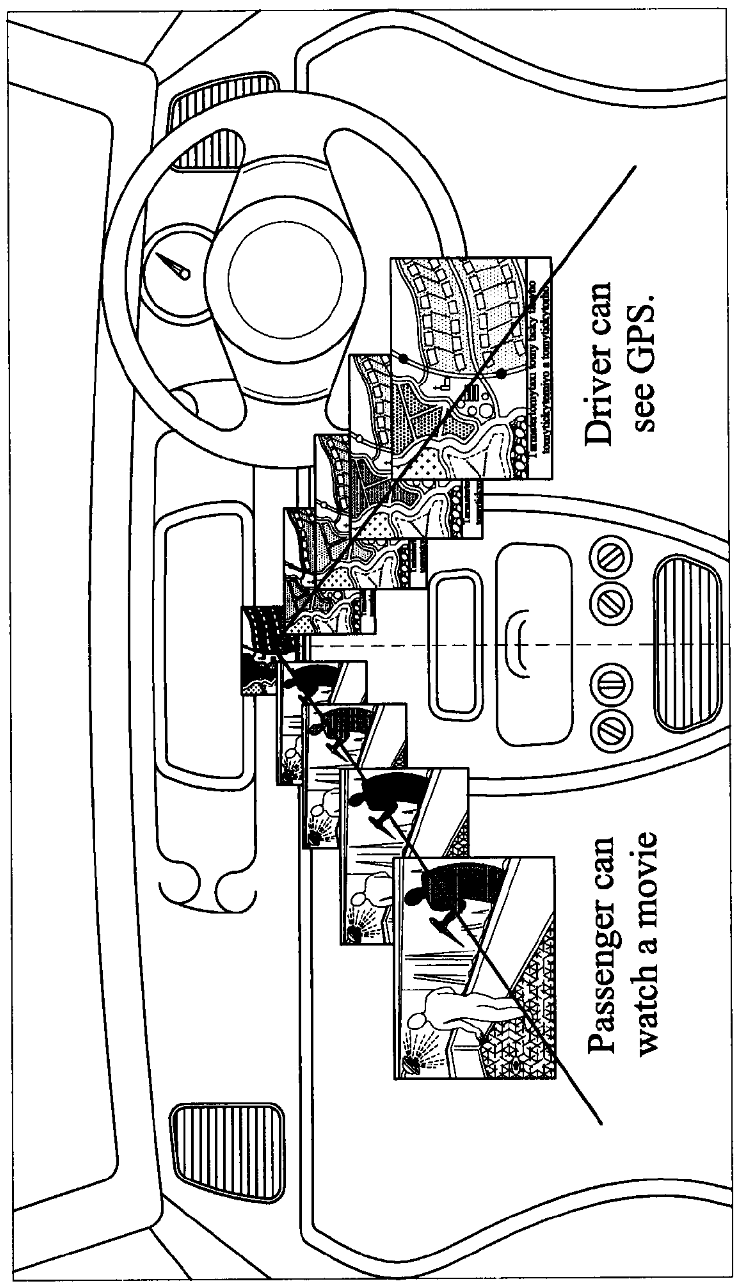


FIG 5

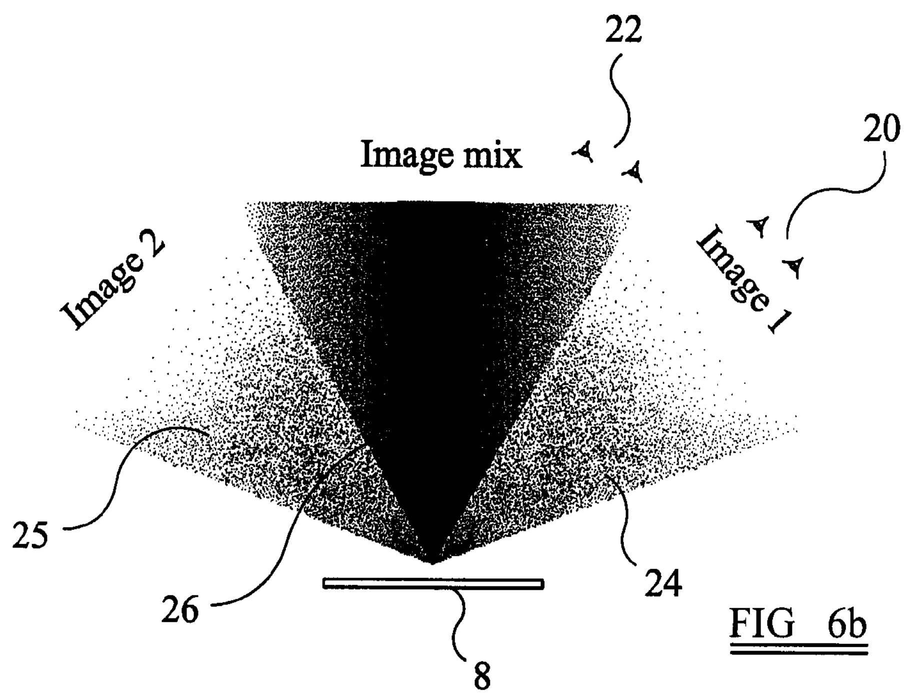

22
Image mix
20
Image 2
Image 1
25
26
24
8

FIG 6b

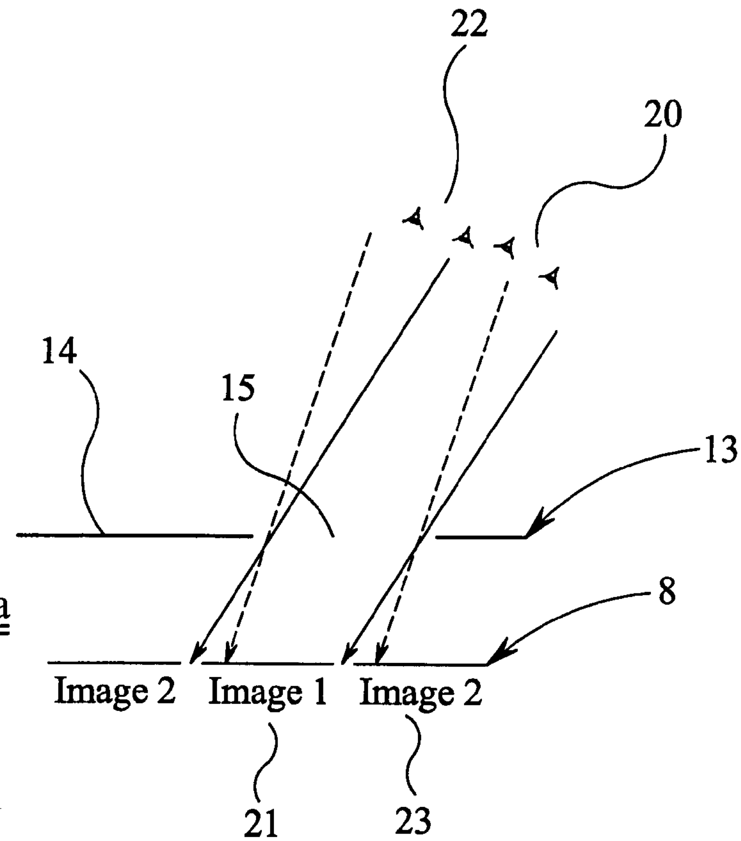
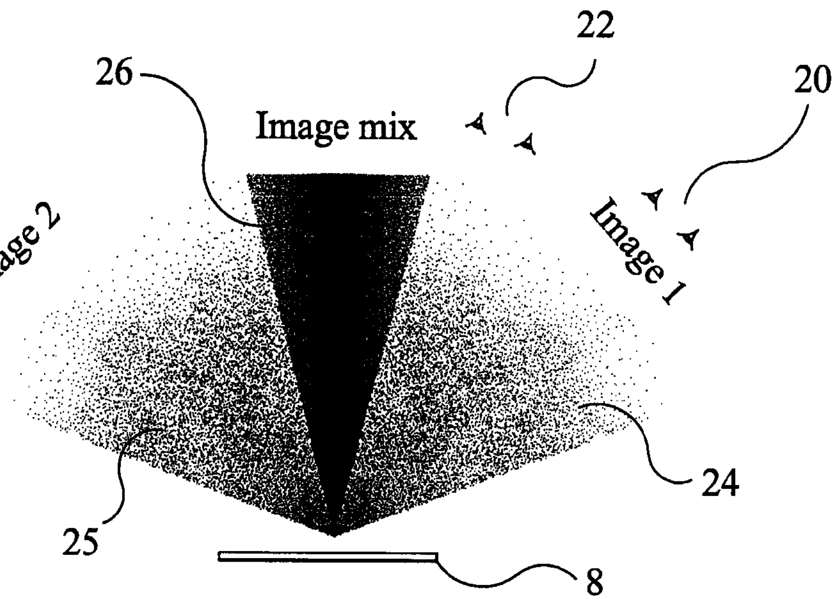
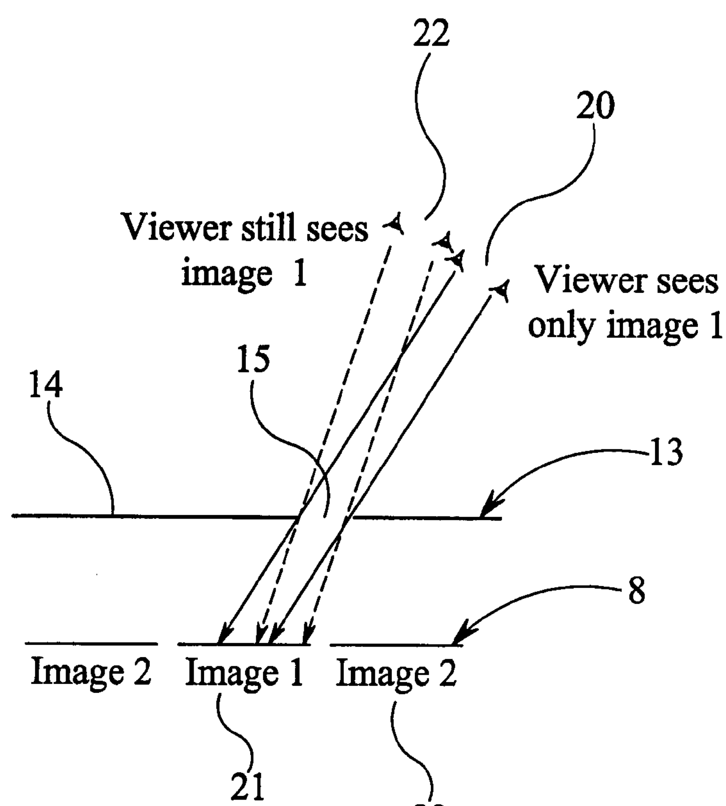

22
20
14
15
13
8
Image 2
Image 1
Image 2
21
23

FIG 6a



22
26
20
Image mix
Image 2
Image 1
24
25
8

FIG 6d



22
20
Viewer still sees image 1
Viewer sees only image 1
15
14
13
8
Image 2
Image 1
Image 2
21
23

FIG 6c

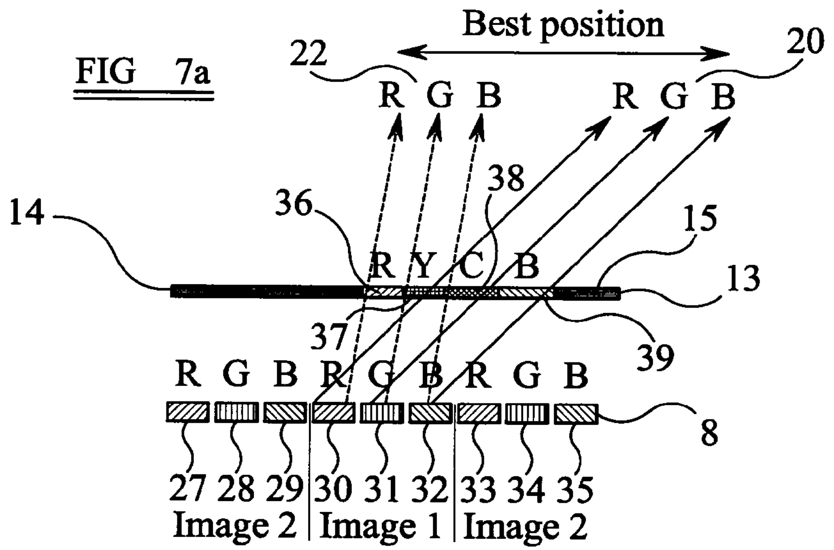


FIG 7a

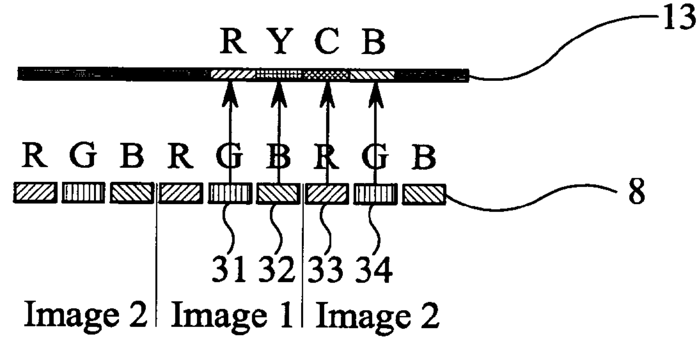


FIG 7b

Light perpendicular to LCD is blocked

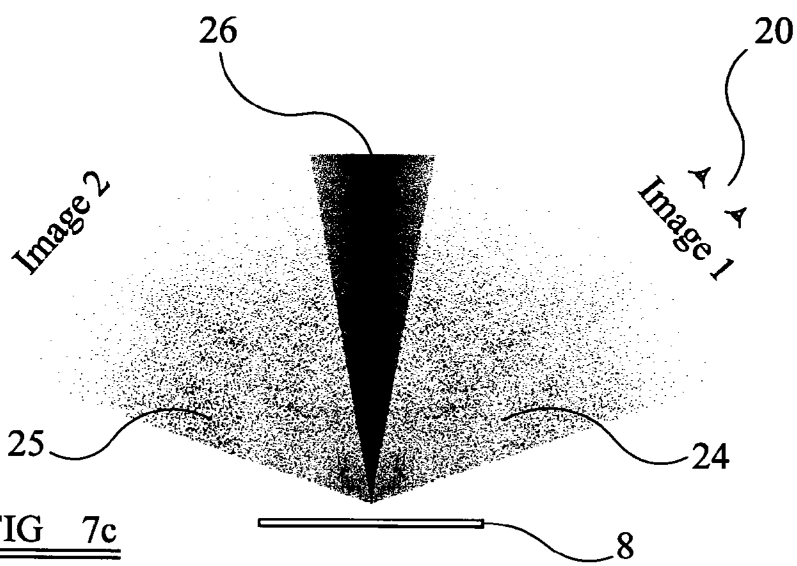


FIG 7c

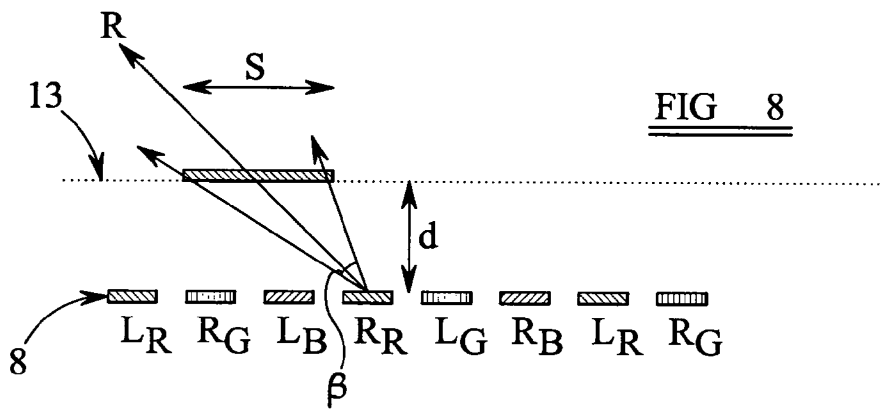
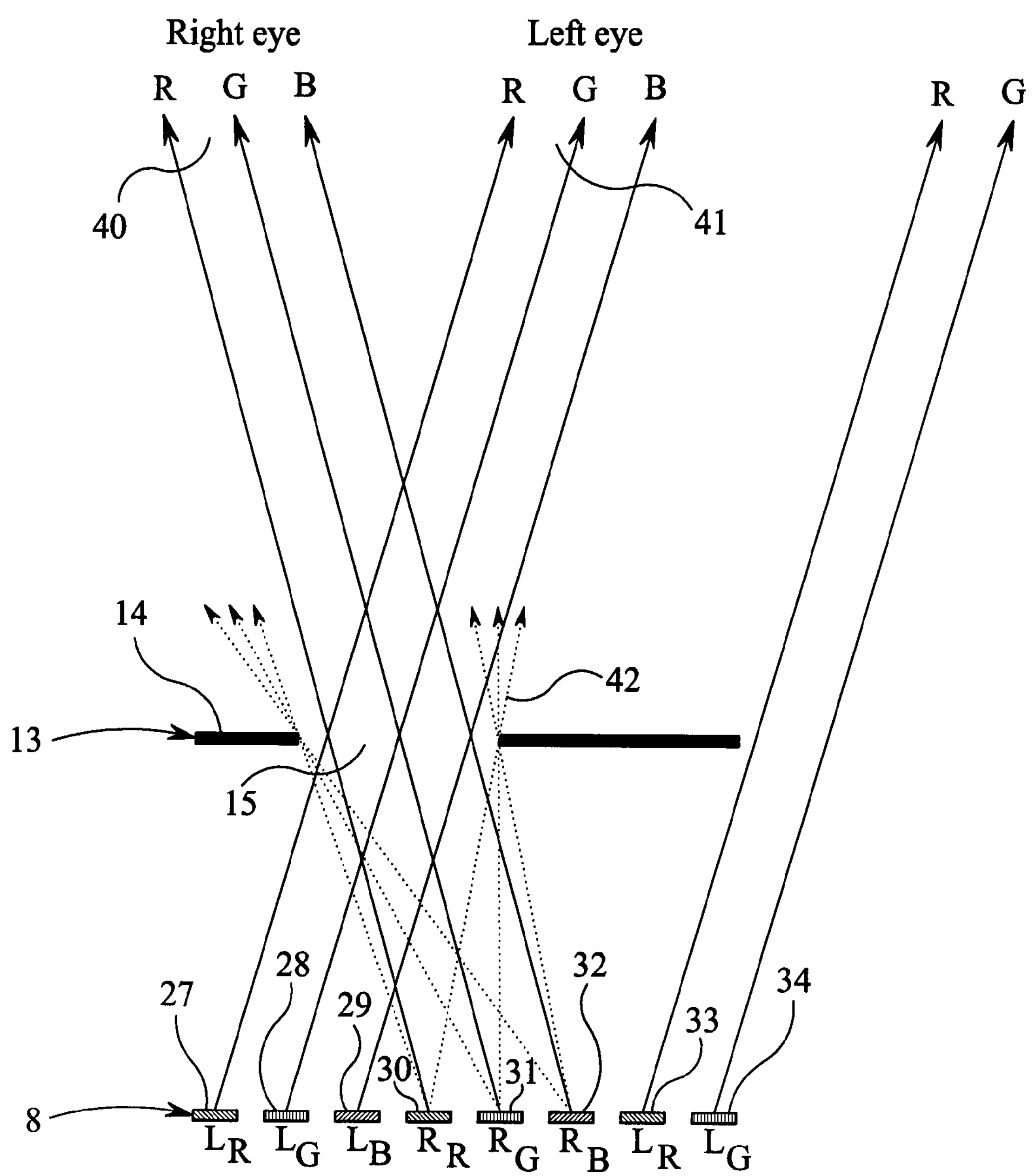


FIG 8

FIG 9


Right eye
Left eye
R G B
R G B
R G
40
41
14
42
13
15
27
28
29
30
31
32
33
34
8
L_R L_G L_B R_R R_G R_B L_R L_G

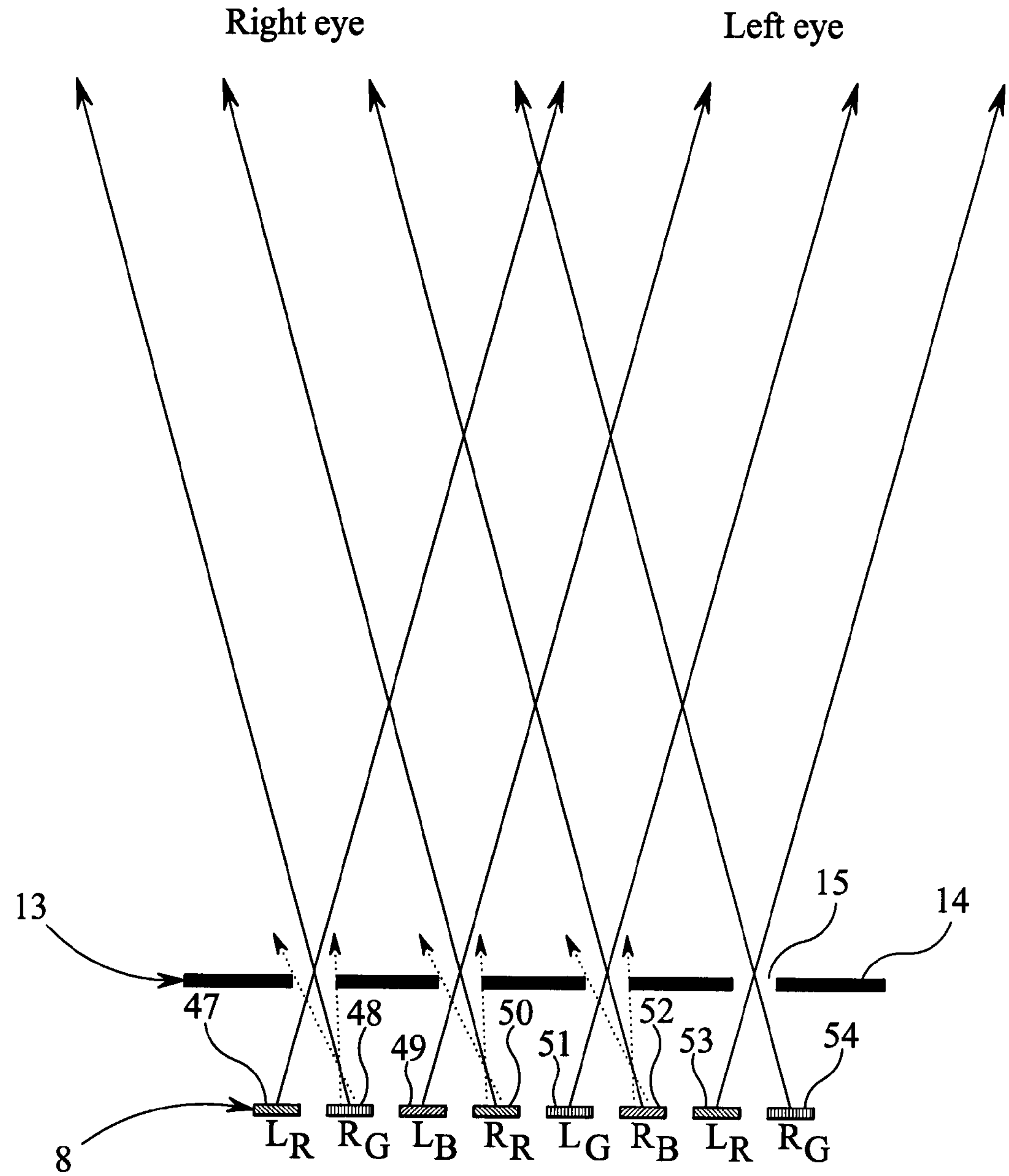

Right eye
Left eye
13
15
14
47
48
49
50
51
52
53
54
8
L_R R_G L_B R_R L_G R_B L_R R_G

FIG 10

FIG 11

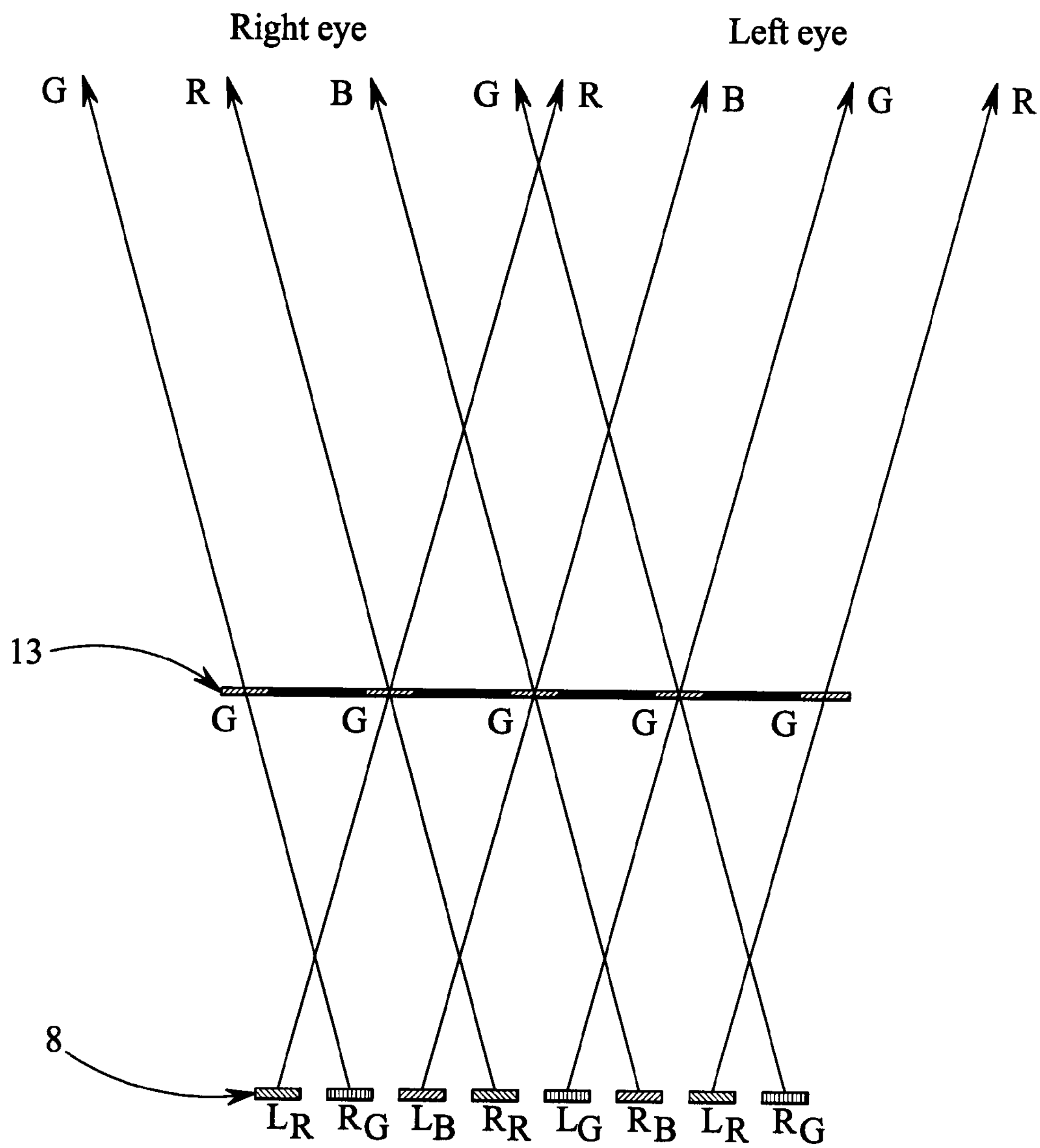


FIG 12

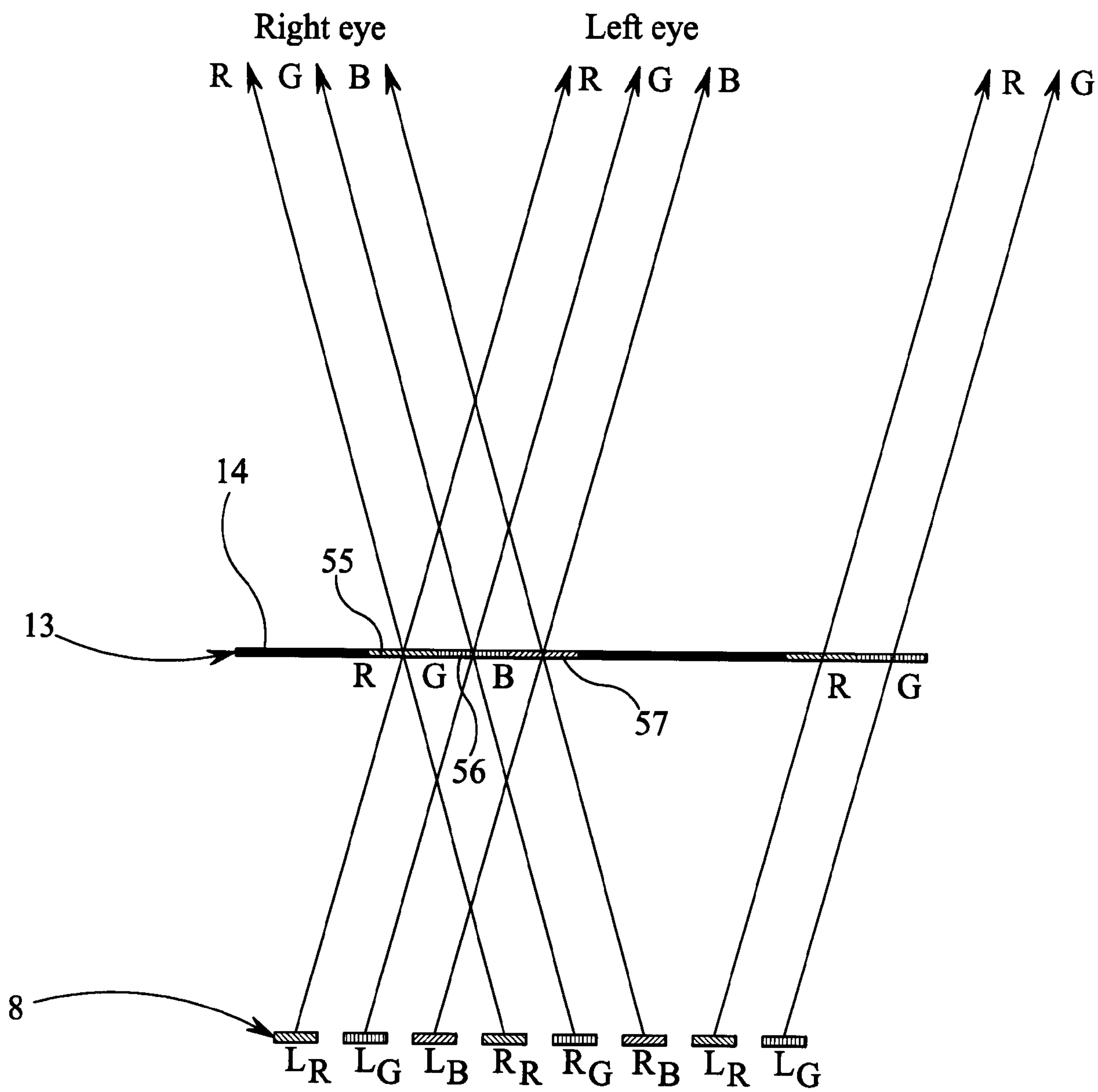
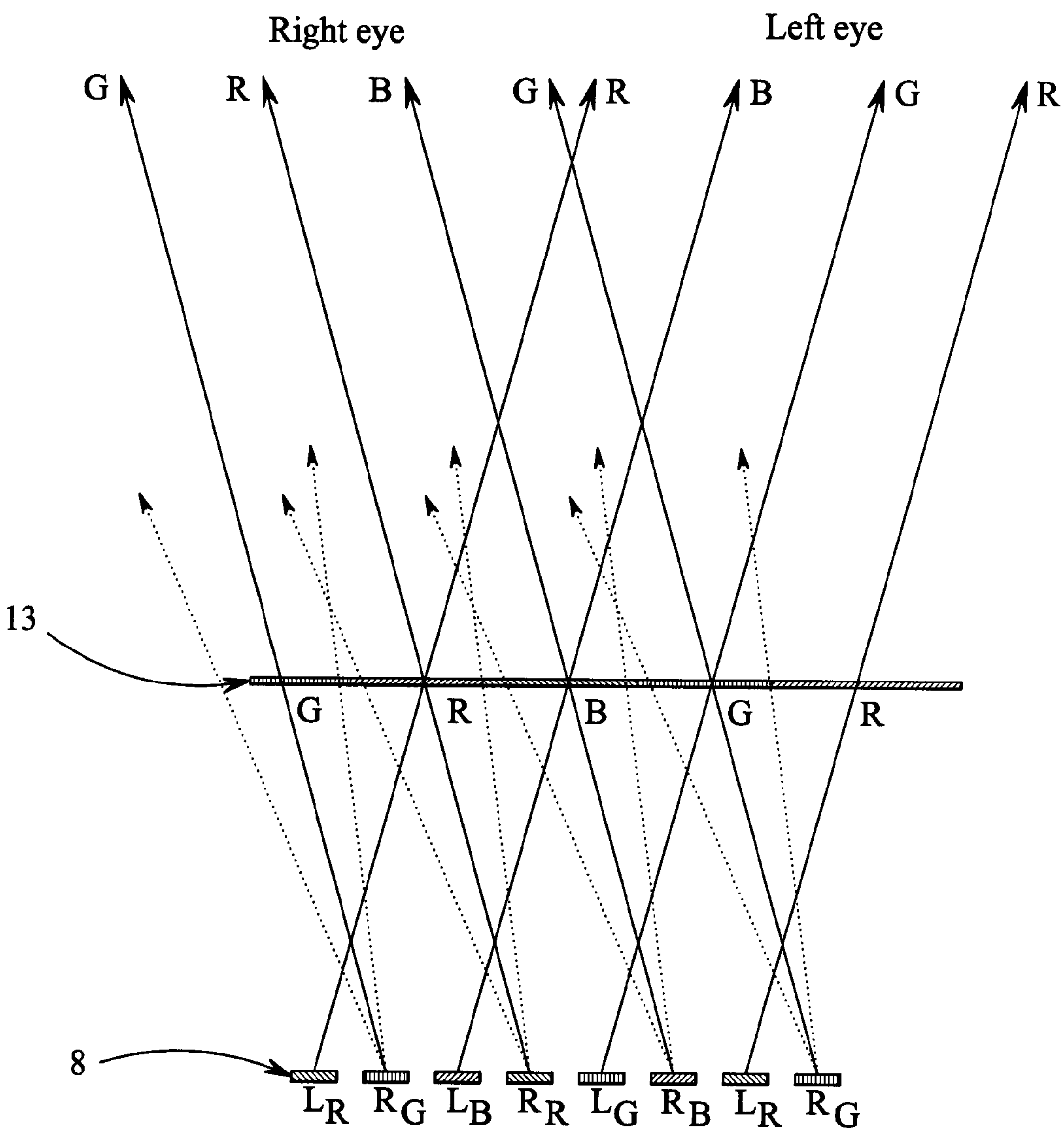

Right eye
Left eye
R
G
B
R
G
B
R
G
14
55
13
R
G
B
R
G
57
56
8
L_R
L_G
L_B
R_R
R_G
R_B
L_R
L_G

FIG 13



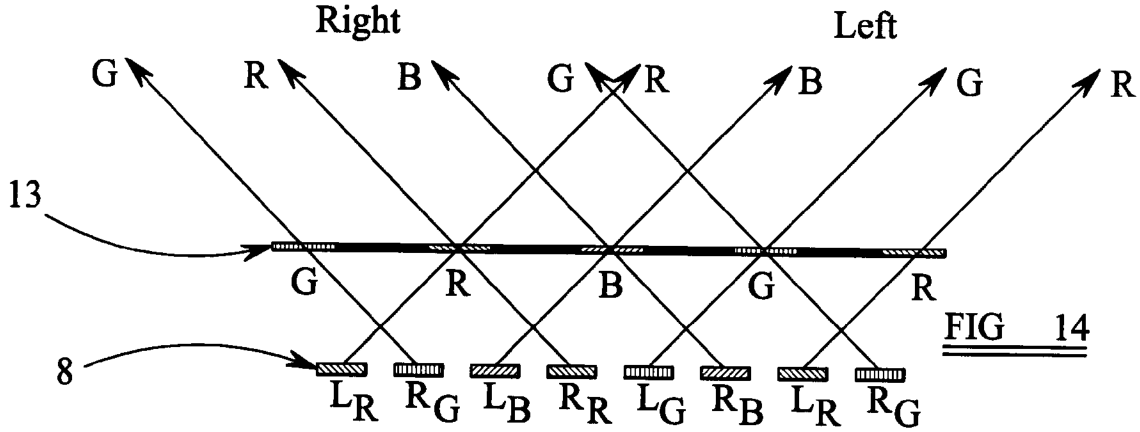


FIG 14

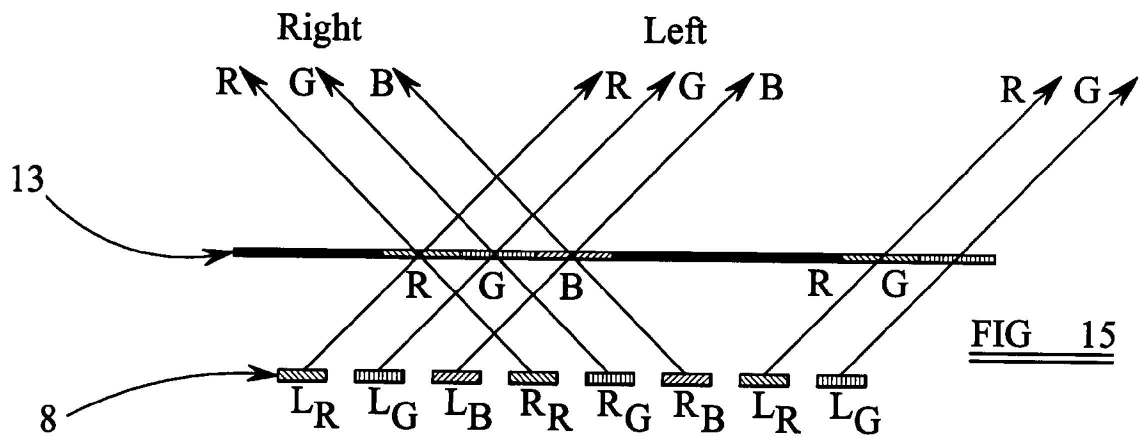


FIG 15

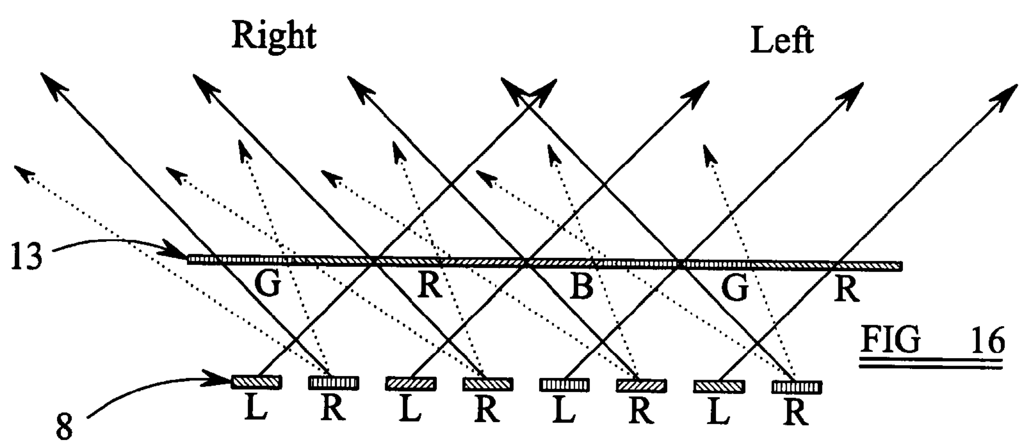


FIG 16

FIG 17a

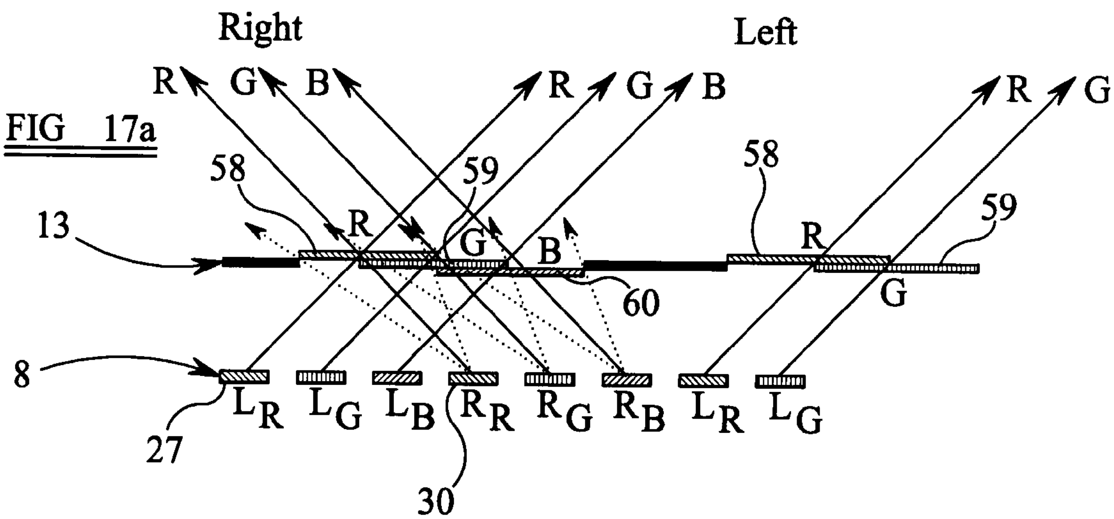


FIG 17b

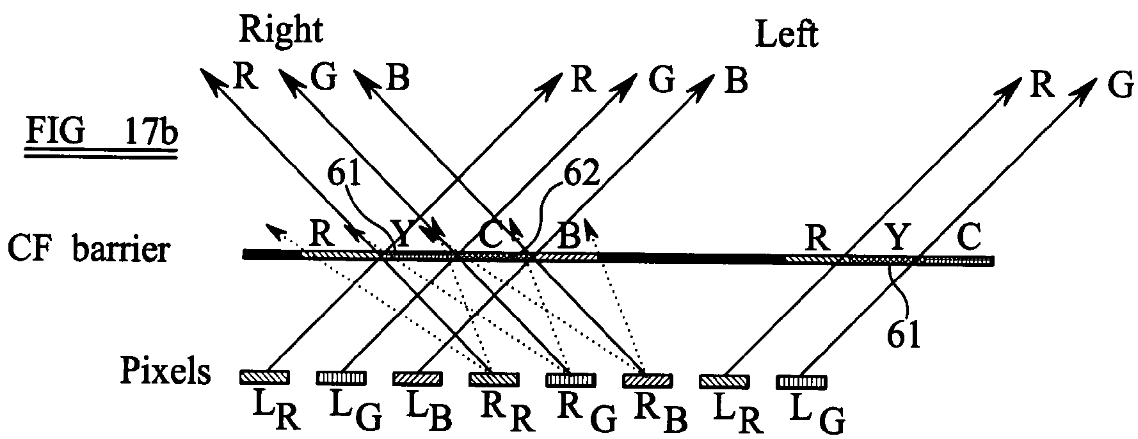


FIG 18

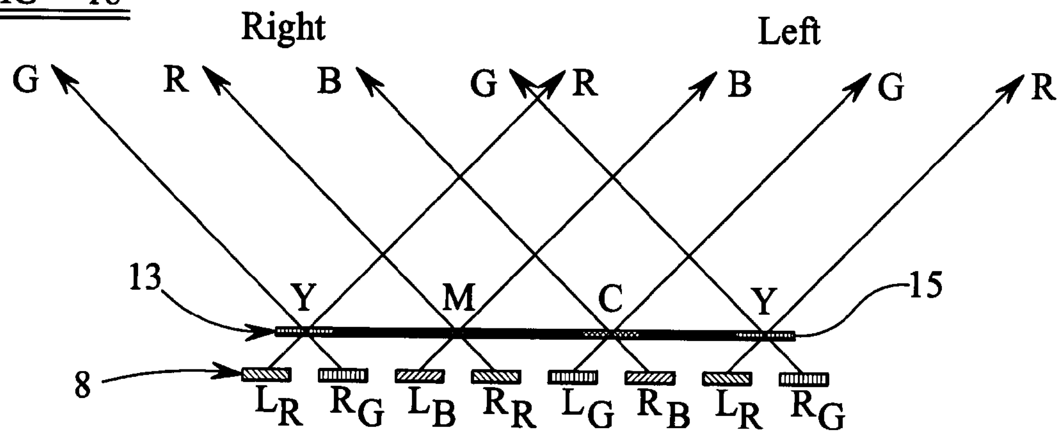


FIG 19a

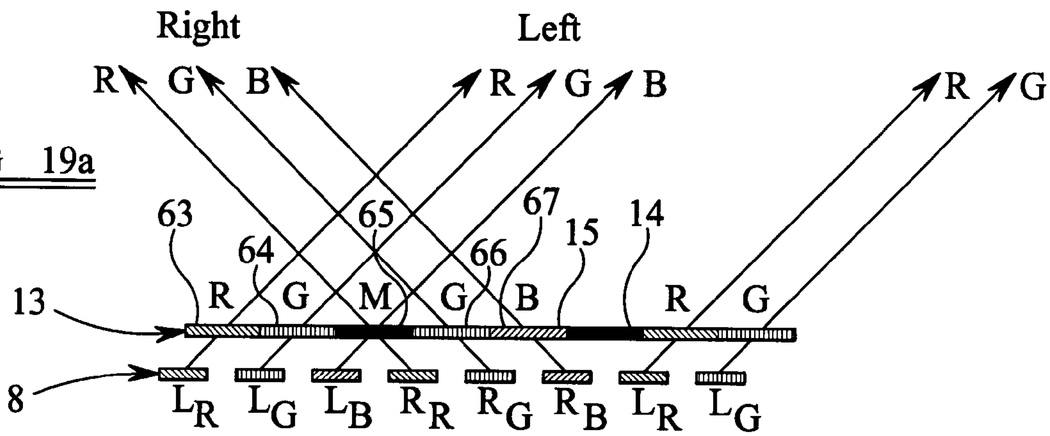


FIG 19b

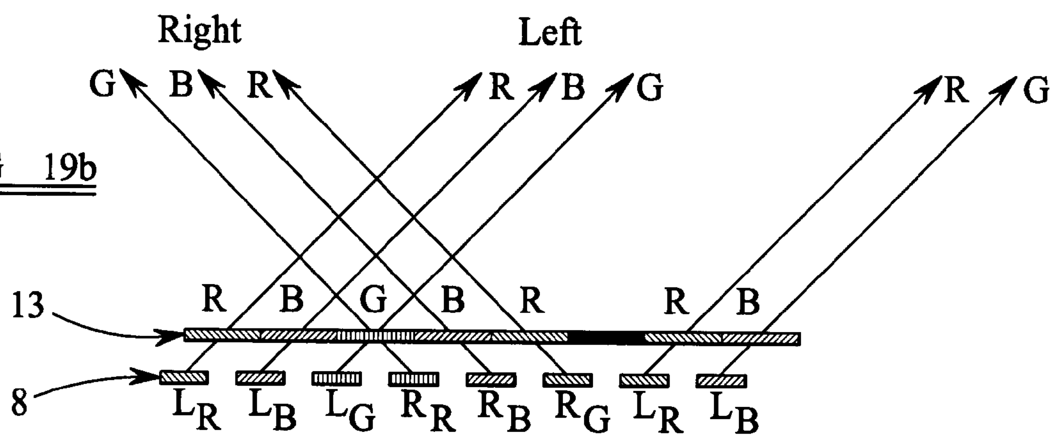


FIG 20a

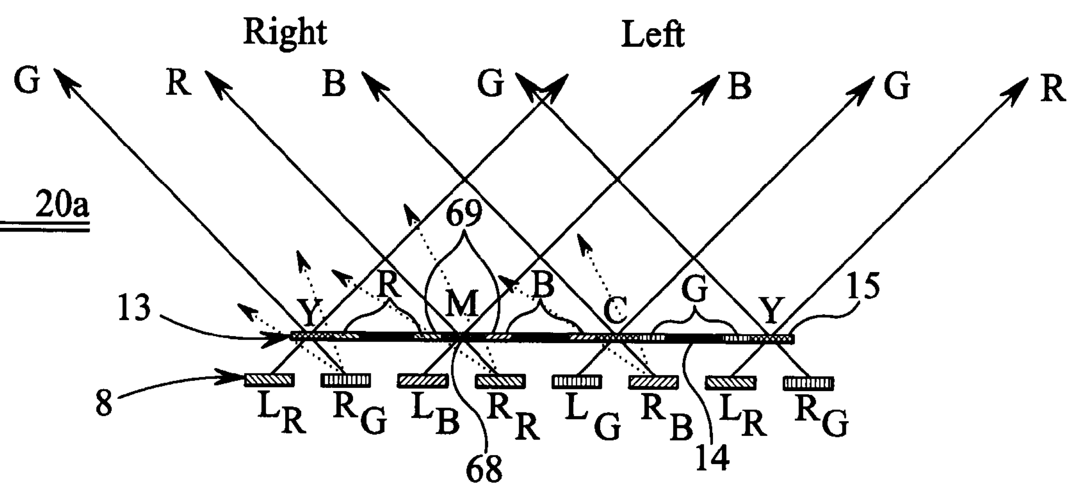


FIG 20b

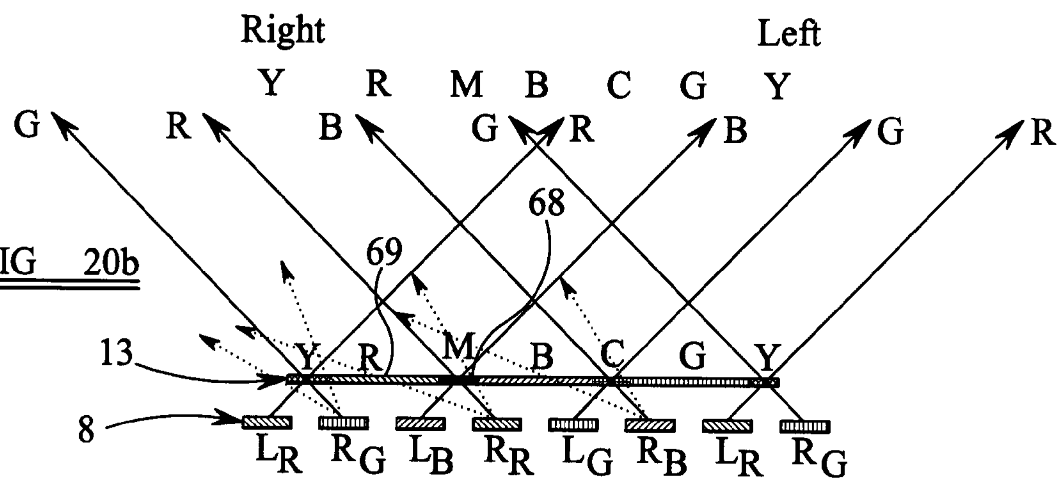


FIG 21a

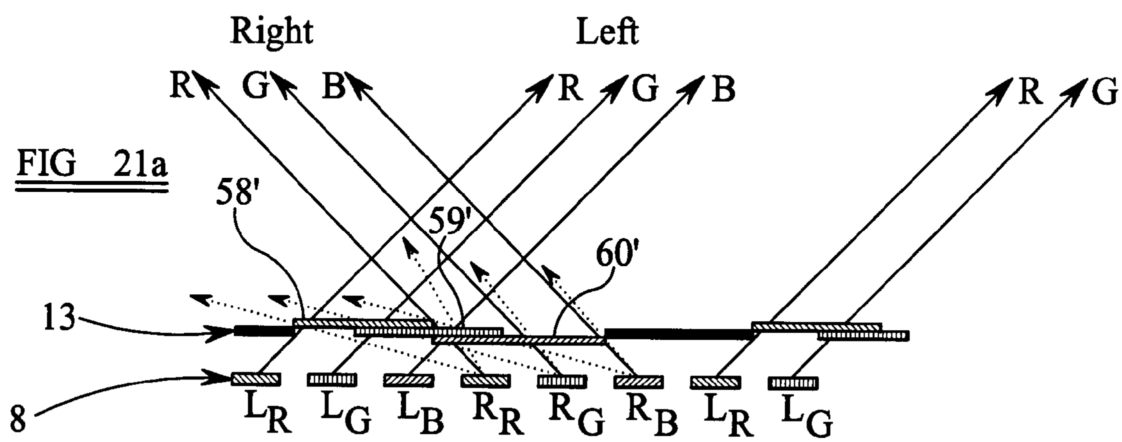


FIG 21b

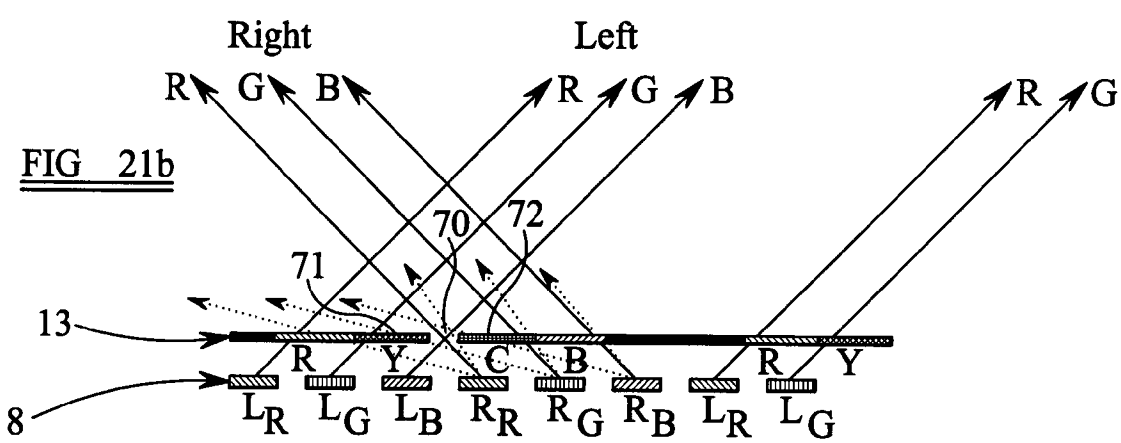


FIG 22a

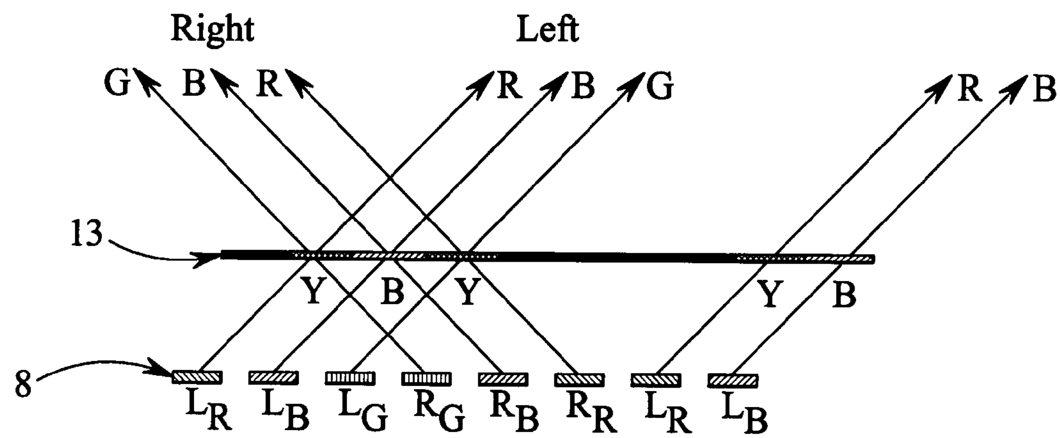


FIG 22b

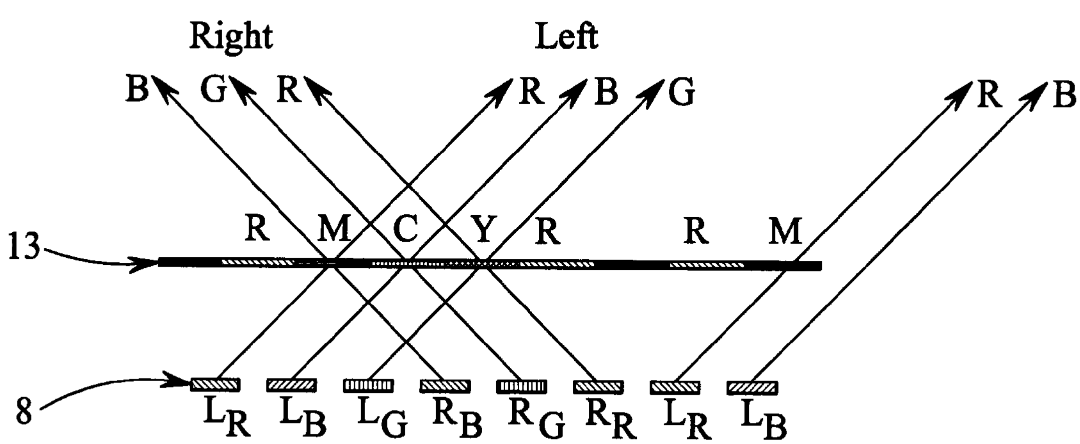


FIG 23a

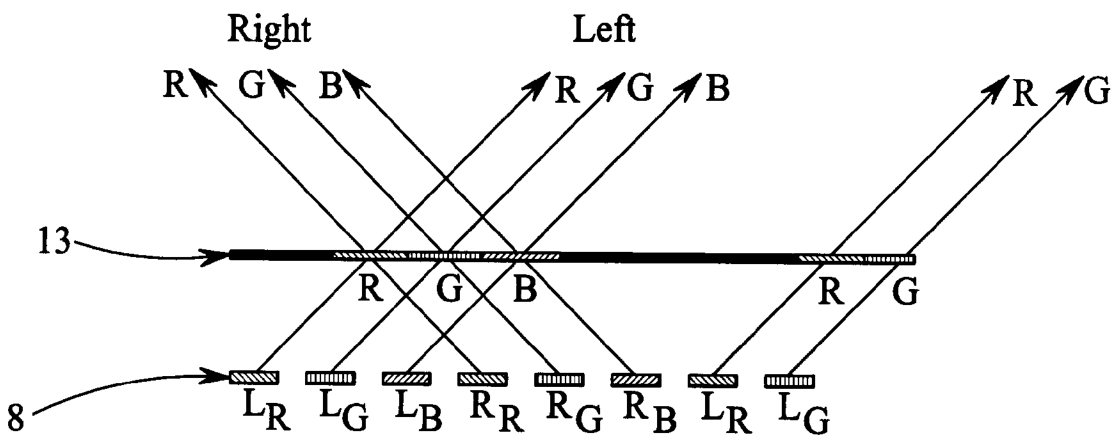
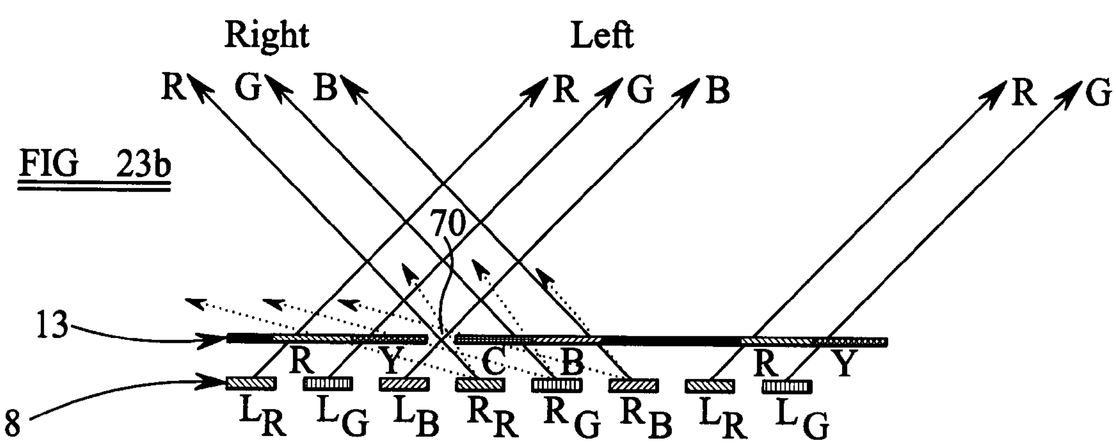


FIG 23b



2405545

A Multiple-View Directional Display

The present invention relates to a multiple-view directional display, which displays two or more images such that each image is visible from a different direction. Thus, two observers who view the display from different directions will see different images to one another. Such an display may be used as, for example, an autostereoscopic display device or a dual view display device.

For many years conventional display devices have been designed to be viewed by multiple users simultaneously. The display properties of the display device are made such that viewers can see the same good image quality from different angles with respect to the display. This is effective in applications where many users require the same information from the display – such as, for example, displays of departure information at airports and railway stations. However, there are many applications where it would be desirable for individual users to be able to see different information from the same display. For example, in a motor car the driver may wish to view satellite navigation data while a passenger may wish to view a film. These conflicting needs could be satisfied by providing two separate display devices, but this would take up extra space and would increase the cost. Furthermore, if two separate displays were used in this example it would be possible for the driver to see the passenger's display if they moved their head, which would be distracting for the driver. As a further example, each player in a computer game for two or more players may wish to view the game from his or her own perspective. This is currently done by each player viewing the game on a separate display screen so that each player sees their own unique perspective on individual screens. However, providing a separate display screen for each player takes up a lot of space, and is not practical for portable games.

To solve these problems, multiple-view directional displays have been developed. One application of a multiple-view directional display is as a 'dual-view display', which can simultaneously display two or more different images, with each image being visible only in a specific direction – so an observer viewing the display device from one

direction will see one image whereas an observer viewing the display device from another, different direction will see a different image. A display that can show different images to two or more users provides a considerable saving in space and cost compared with use of two or more separate displays.

Examples of possible applications of multiple-view directional display devices have been given above, but there are many other applications. For example, they may be used in aeroplanes where each passenger is provided with their own individual in-flight entertainment programmes. Currently each passenger is provided with an individual display device, typically in the back of the seat in the previous row. Using a multiple view directional display could provide considerable savings in cost, space and weight since it would be possible for one display to serve two or more passengers while still allowing each passenger to select their own choice of film.

A further advantage of a multiple-view directional display is the ability to preclude the users from seeing each other's views. This is desirable in applications requiring security such as banking or sales transactions, for example using an automatic teller machine (ATM), as well as in the above example of computer games.

A further application of a multiple view directional display is in producing a three-dimensional display. In normal vision, the two eyes of a human perceive views of the world from different perspectives, owing to their different location within the head. These two perspectives are then used by the brain to assess the distance to the various objects in a scene. In order to build a display which will effectively display a three dimensional image, it is necessary to re-create this situation and supply a so-called "stereoscopic pair" of images, one image to each eye of the observer.

Three dimensional displays are classified into two types depending on the method used to supply the different views to the eyes. A stereoscopic display typically displays both images of a stereoscopic image pair over a wide viewing area. Each of the views is encoded, for instance by colour, polarisation state, or time of display. The user is

required to wear a filter system of glasses that separate the views and let each eye see only the view that is intended for it.

An autostereoscopic display displays a right-eye view and a left-eye view in different directions, so that each view visible only from respective defined regions of space. The region of space in which an image is visible across the whole of the display active area is termed a "viewing window". If the observer is situated such that their left eye is in the viewing window for the left eye view of a stereoscopic pair and their right eye is in the viewing window for the right-eye image of the pair, then a view will be seen by each eye of the observer and a three-dimensional image will be perceived. An autostereoscopic display requires no viewing aids to be worn by the observer.

An autostereoscopic display is similar in principle to a dual-view display. However, the two images displayed on a autostereoscopic display are the left-eye and right-eye images of a stereoscopic image pair, and so are not independent from one another. Furthermore, the two images are displayed so as to be visible to a single observer, with one image being visible to each eye of the observer.

For a flat panel autostereoscopic display, the formation of the viewing windows is typically due to a combination of the picture element (or "pixel") structure of the image display unit of the autostereoscopic display and an optical element, generically termed a parallax optic. An example of a parallax optic is a parallax barrier, which is a screen with transmissive regions, often in the form of slits, separated by opaque regions. This screen can be set in front of or behind a spatial light modulator (SLM) having a two-dimensional array of picture elements to produce an autostereoscopic display.

Figure 1 is a plan view of a conventional multiple view directional device, in this case an autostereoscopic display. The directional display 1 consists of a spatial light modulator (SLM) 4 that constitutes an image display device, and a parallax barrier 5. The SLM of Figure 1 is in the form of a liquid crystal display (LCD) device having an active matrix thin film transistor (TFT) substrate 6, a counter-substrate 7, and a liquid

crystal layer 8 disposed between the substrate and the counter substrate. The SLM is provided with addressing electrodes (not shown) which define a plurality of independently-addressable picture elements, and is also provided with alignment layers (not shown) for aligning the liquid crystal layer. Viewing angle enhancement films 9 and linear polarisers 10 are provided on the outer surface of each substrate 6, 7. Illumination 11 is supplied from a backlight (not shown).

The parallax barrier 5 comprises a substrate 12 with a parallax barrier aperture array 13 formed on its surface adjacent the SLM 4. The aperture array comprises vertically extending (that is, extending into the plane of the paper in Figure 1) transparent apertures 15 separated by opaque portions 14. An anti-reflection (AR) coating 16 is formed on the opposite surface of the parallax barrier substrate 12 (which forms the output surface of the display 1).

The pixels of the SLM 4 are arranged in rows and columns with the columns extending into the plane of the paper in Figure 1. The pixel pitch (the distance from the centre of one pixel to the centre of an adjacent pixel) in the row or horizontal direction being p. The width of the vertically-extending transmissive slits 15 of the aperture array 13 is 2w and the horizontal pitch of the transmissive slits 15 is b. The plane of the barrier aperture array 13 is spaced from the plane of the liquid crystal layer 8 by a distance s.

In use, the display device 1 forms a left-eye image and a right-eye image, and an observer who positions their head such that their left and right eyes are coincident with the left-eye viewing window 2 and the right-eye viewing window 3 respectively will see a three-dimensional image. The left and right viewing windows 2,3 are formed in a window plane 17 at the desired viewing distance from the display. The window plane is spaced from the plane of the aperture array 13 by a distance r_o. The windows 2,3 are contiguous in the window plane and have a pitch e corresponding to the average separation between the two eyes of a human. The half angle to the centre of each window 10, 11 from the normal axis to the display normal is α_s.

The pitch of the slits 15 in the parallax barrier 5 is chosen to be close to an integer multiple of the pixel pitch of the SLM 4 so that groups of columns of pixels are associated with a specific slit of the parallax barrier. Fig. 1 shows a display device in which two pixel columns of the SLM 4 are associated with each transmissive slit 15 of the parallax barrier.

Figure 2 shows the angular zones of light created from an SLM 4 and parallax barrier 5 where the parallax barrier has a pitch of an exact integer multiple of the pixel column pitch. In this case, the angular zones coming from different locations across the display panel surface intermix and a pure zone of view for image 1 or image 2 (where 'image 1' and 'image 2' denote the two images displayed by the SLM 4) does not exist. In order to address this, the pitch of the parallax barrier is preferably reduced slightly so that it is slightly less than an integer multiple of the pixel column pitch. As a result, the angular zones converge at a pre-defined plane (the "window plane") in front of the display. This effect is illustrated in Figure 3 of the accompanying drawings, which shows the image zones created by an SLM 4 and a modified parallax barrier 5'. The viewing regions, when created in this way, are roughly kite-shaped in plan view.

Figure 4 is a plan view of another conventional multiple view directional display device 1'. This corresponds generally to the display device 1 of Figure 1, except that the parallax barrier 5 is placed behind the SLM 4, so that it is between the backlight and SLM 4. This device may have the advantages that the parallax barrier is less visible to an observer, and that the pixels of the display appear to be closer to the front of the device. Furthermore, although figures 1 and 4 each show a transmissive display device illuminated by a backlight, reflective devices that use ambient light (in bright conditions) are known. In the case of a transmissive and reflective device, the rear parallax barrier of Figure 4 will absorb none of the ambient lighting for a barrier that is switched off to give a 2-D display mode. This is an advantage if the display has a 2D mode that uses reflected light.

In the display devices of figures 1 and 4, a parallax barrier is used as the parallax optic. Other types of parallax optic are known. For example, lenticular lens arrays may be used to direct interlaced images in different directions, so as to form a stereoscopic image pair or to form two or more each in a different direction.

Holographic methods of image splitting are known, but in practice these methods suffer from viewing angle problems, pseudoscopic zones and a lack of easy control of the images.

Another type of parallax optic is a micropolariser display, which uses a polarised directional light source and patterned high precision micropolariser elements aligned with the pixels of the SLM. Such a display offers the potential for high window image quality, a compact device, and the ability to switch between a 2D display mode and a 3D display mode. The dominant requirement when using a micropolariser display as a parallax optic is the need to avoid parallax problems when the micropolariser elements are incorporated into the SLM.

Where a colour display is required, each pixel of the SLM 4 is generally given a filter associated with one of the three primary colours. By controlling groups of three pixels, each with a different colour filter, all visible colours may be produced. In an autostereoscopic display each of the stereoscopic image channels must contain sufficient of the colour filters for a balanced colour output. Many SLMs have the colour filters arranged in vertical columns, owing to ease of manufacture, so that all the pixels in a given column have the same colour filter associated with them. If a parallax optic is disposed on such an SLM with three pixel columns associated with each slit or lenslet of the parallax optic, then each viewing region will see pixels of one colour only. Care must be taken with the colour filter layout to avoid this situation. Further details of suitable colour filter layouts are given in are contained in EP-A-0 752 610.

The function of the parallax optic in a directional display device such as those shown in figures 1 and 4 is to restrict light transmitted through the pixels of the SLM 4 to certain

output angles. This restriction defines the angle of view of each of the pixel columns behind a given element of the parallax optic (such as for example a transmissive slit). The angular range of view of each pixel is determined by the pixel pitch p, the separation s between the plane of the pixels and the plane of the parallax optic, and the refractive index n of the material between the plane of the pixels and the plane of the parallax optic (which in the display of Figure is the substrate 7). H Yamamoto et al. show, in "Optimum parameters and viewing areas of stereoscopic full-colour LED displays using parallax barrier", IEICE Trans. Electron., vol. E83-C, No. 10, p1632 (2000), that the angle of separation between images in an autostereoscopic display depends on the distance between the display pixels and the parallax barrier.

The half-angle α of Figure 1 or 4 is given by:

$$\sin\alpha = n\sin\left(\arctan\left(\frac{p}{2s}\right)\right) \qquad (1)$$

One problem with many existing multiple view directional displays is that the angular separation between the two images is too low. In principle, the angle 2α between viewing windows may be increased by increasing the pixel pitch p, decreasing the separation between the parallax optic and the pixels s, or by increasing the refractive index of the substrate n.

Co-pending UK patent application No. 0315170.1 proposes increasing the angle of separation between the viewing windows of a multiple-view directional display by increasing the effective pitch of the pixels. This can be achieved by grouping the pixels together so that two or more adjacent pixels show the same image. If colour sub pixels show image 1 and image 2 alternately, this is termed NP1. If pairs of colour sub pixels show image 1 and image 2 alternately, this is termed NP2. If groups of three colour sub pixels show image 1 and image 2 alternately, this is termed NP3. This has the disadvantage that the pitch of the parallax barrier must increase as the effective pixel

pitch increases which, in turn, increases the visibility of the parallax barrier to an observer.

Figure 5 shows a dual-view display installed in a motor vehicle. The dual-view display 18 is installed in the dashboard 19 of a motor vehicle. One image displayed on the dual-view display is a map, which may also show the position of the vehicle if the vehicle is fitted with a GPS location system. This view is made visible to the driver of the vehicle. The other image displayed by the dual-view display 19 is an entertainment programme, such as a film, and this is made visible to, for example, the front seat passenger in the vehicle. Use in motor vehicles, particularly in motor cars, is an increasingly important application of dual-view displays.

Figure 6 illustrates a problem encountered by dual-view displays having a conventional parallax barrier 13 consisting of an array of opaque 14 and transparent 15 portions. As shown in Figure 6a, when the viewer is located at the correct position 20 for viewing image 1, he can see only pixel 21 through the slit 15. However, if the viewer moves to a different position 22, he can see two adjacent pixels 21,23, displaying different images. He will thus be able to see both images at once from thus position. Figure 6b shows the angular regions 24,25 in which a viewer will see image 1 and image 2, respectively. In the central region 26 he will be able to see both images at once. This is known as "crosstalk".

One solution to this problem is to reduce the width of the transparent portion 15, as shown in Figure 6c. Now the viewer will see pixel 21 displaying image 1, without being able to see the adjacent pixel 23, from a variety of positions 20,22. As shown in Figure 6d, the region 26 in which the viewer can see both images is reduced, and the regions 24,25 in which image 1 only or image 2 only are visible are increased. Unfortunately, the reduction in the width of the transparent slit 15 leads to a reduction in the brightness of the image as seen by the viewer. In order to create sufficient freedom of movement of a viewer's head, the width of the transparent slit 15 must be

about half that of a pixel, so the panel is about a quarter of the brightness of a non-multiview panel.

G Hamagishi et al describe, in "Invited paper: A display System with 2-D/3-D Compatibility", SID 98 Digest, 1998, p915, the use of two parallax barriers in an autostereoscopic display. Depending on the slit widths of the barriers, the two barriers can either prevent the viewer seeing a crosstalk region between the two views (one for each eye), or remove variations in intensity as the viewer moves across the panel.

JP-A-8146346 discloses an LCD whose pixels are grouped together in sets of three. The groups of pixels show slices of left and right images alternately (NP3 interlacing). A colour filter parallax barrier is suggested to allow light from the groups of pixels to be emitted in different directions. The colour filter barrier and the LCD colour filters use the same thee primary colours.

JP-A-8146347 proposes a similar design to JP-A-8146346. Each slit of the colour filter barrier only allows light to pass from one LCD colour filter.

JP-A-8163605 discloses another colour filter barrier design for an LCD whose pixels are grouped into sets of three. Each colour filter barrier slit is the same colour as its corresponding pixel.

US patent no. 5751479 discloses a colour filter barrier design for an LCD where left and right images are interlaced pixel by pixel (NP1 interlacing). A colour filter barrier is used to send left and right images in appropriate directions. Each portion of colour on the colour filter barrier is about twice the width of a pixel.

US-A-2003/0067539 relates to colour filter barriers relating to more than two views (multi-view),

US patent no. 6392690 discloses a NP1 parallax barrier with coloured slits. This means the colour filters and barrier can both be in the same plane. There is only one layer of colour filters required (i.e. there are no parallax effects between two sets of colour filters).

In accordance with a first aspect of the present invention there is provided a multiple-view directional display, comprising: an image display device comprising a set of picture elements, and a parallax optic comprising an array of colour filters.

A display in accordance with the invention may be viewed from a wider variety of angles than was previously possible. Thus the head freedom of the user is increased without compromising the brightness of the display. In addition, the region near 90° to the display, in which crosstalk occurs, may be reduced. This can prevent viewers of a dual-display device from seeing both images simultaneously.

Each colour filter is preferably aligned with a respective set of the picture elements. The colour filters may be arranged in apertures in the parallax optic.

In a preferred embodiment, each picture element is arranged to emit light of a primary colour, and at least one of the colour filters is arranged to transmit light of more than one primary colour. The use of colour filters transmitting secondary colours allows much greater freedom in the design of the parallax optic. This in turn allows the optic to be placed closer to the image display device. It also facilitates the provision of a "black" central window to reduce the occurrence of crosstalk.

In addition, the parallax optic may include at least one substantially transparent region for transmitting light of all three primary colours. Alternatively, all of the colour filters may be of a secondary colour arranged to transmit two primary colours only.

The picture elements may show portions of two images alternately (known as NP1 interlacing). Alternatively, the pixels may be grouped in pairs or threes showing each

image (NP2 and NP3 interlacing). It will be apparent that higher numbers of pixels may be grouped together to show each image, although the design of the colour filters will become more difficult.

The colour filters are preferably arranged in a periodically repeating pattern. The picture elements may also be arranged to emit coloured light in a periodically repeating pattern, and the pattern of the colour filters and picture elements may be different. The number of colour filters in a single period of the pattern is preferably greater than three.

In a preferred embodiment, one period of the colour filter pattern includes: a first filter arranged to transmit light of only a first primary colour; a second filter arranged to transmit light of the first primary colour and a second primary colour; a third filter arranged to transmit light of the second primary colour and a third primary colour; and a fourth filter arranged to transmit light of only the third primary colour.

As an alternative, one period of the colour filter pattern may include: a first filter arranged to transmit light of only a first primary colour; a second filter arranged to transmit light of only a second primary colour; a third filter arranged to transmit light of the first primary colour and a third primary colour; a fourth filter arranged to transmit light of the second primary colour; and a fifth filter arranged to transmit light of only the third primary colour.

In a further alternative, one period of the colour filter pattern may includes: a first filter arranged to transmit light of only a first primary colour; a second filter arranged to transmit light of only a second primary colour; a third filter arranged to transmit light of only a third primary colour; a fourth filter arranged to transmit light of the second primary colour; and a fifth filter arranged to transmit light of the first primary colour.

In the above described embodiment, the third primary colour is preferably green. This allows enables the green (third) colour filter to be in the middle of the pattern. This has the advantage that, if the green colour filter leaks some red and blue the effects are

insignificant. This helps crosstalk problems caused by leakage through the colour filters.

The number of elements in one period of the picture element pattern may be greater than three. For example, the picture element pattern may include elements arranged to emit primary colours in the order first, second, third, third, second, first.

In another embodiment, one period of the colour filter pattern includes: a first filter arranged to transmit light of a first primary colour and a second primary colour; a second filter arranged to transmit light of only a third primary colour; and a third filter arranged to transmit light of the first and second primary colours. In this case one period of the picture element pattern may include elements arranged to emit primary colours in the order first, third, second, second, third, first.

In a yet further embodiment, one period of the colour filter pattern includes: a first filter arranged to transmit light of only a first primary colour; a second filter arranged to transmit light of a first primary colour and a second primary colour; a third filter arranged to transmit light of the second primary colour and a third primary colour; a fourth filter arranged to transmit light of the third and first primary colours; and a fifth filter arranged to transmit light only of the first primary colour.

The width of each colour filter is preferably substantially the same as the spacing of the picture elements. One period of the colour filter pattern may further include an opaque mask. However, the opaque mask will not always be necessary.

In some embodiments the colour filters may be of varying width, allowing close control of the behaviour of light issuing from the picture elements.

Further embodiments include an arrangement in which one period of the colour filter pattern includes: a first filter arranged to transmit light of only a first primary colour; a second filter arranged to transmit light of the first primary colour and a second primary

colour; a third filter arranged to transmit light of only the second primary colour; a first opaque mask; a fourth filter arranged to transmit light of only the second primary colour; a fifth filter arranged to transmit light of the second primary colour and a third primary colour; a sixth filter arranged to transmit light of only the third primary colour; a second opaque mask; a seventh filter arranged to transmit light of only the third primary colour; an eighth filter arranged to transmit light of the third and first primary colours; a ninth filter arranged to transmit light of only the first primary colour; and a third opaque mask.

In this arrangement, the second, fifth and eighth filters may be wider than the first, third, fourth, sixth, seventh and ninth filters.

In a yet further embodiment, one period of the colour filter pattern includes: a first filter arranged to transmit light of only a first primary colour; a second filter arranged to transmit light of the first primary colour and a second primary colour; a third filter arranged to transmit light of only the second primary colour; a fourth filter arranged to transmit light of the second primary colour and a third primary colour; a fifth filter arranged to transmit light of only the third primary colour; and a sixth filter arranged to transmit light of the third and first primary colours. The first, third and fifth filters are preferably wider than the second, fourth and sixth filters.

In an alternative embodiment, one period of the colour filter pattern includes: a first filter arranged to transmit light of only a first primary colour; a second filter arranged to transmit light of the first primary colour and a second primary colour; a transparent portion arranged to transmit light of all three primary colours; a third filter arranged to transmit light of the second primary colour and a third primary colour; and a fourth filter arranged to transmit light of only the third primary colour. The transparent portion is preferably narrower than the colour filters.

The colour filters may be switchable, enabling the location of the image windows to be adjusted in response to movement of the viewer or to enable the display to be switched between use as a dual-view display and a single-view display.

The display is preferably a dual-view display.

The colour filters are preferably arranged such that there is a region at 90° to the display which appears dark to the viewer.

In accordance with a second aspect of the present invention there is provided a parallax optic comprising an array of colour filters, at least one of which transmits more than one primary colour.

In another embodiment, the backlight may emit light of different colours, removing the need for additional colour filters. Thus in accordance with a third aspect of the invention there is provided a multiple-view directional display, comprising an image display device comprising a set of picture elements illuminated by an array of light sources, at least one of which emits light of a secondary colour.

Existing multiple view displays suffer from limited possible head movement for the viewer when viewing one of the multiple images of the display. An additional problem is crosstalk in the region between two views of the display. Embodiments of the present invention enable the increase of the available head movement without compromising the brightness of the display. Some embodiments also enable the provision of a central black window which reduces or eliminates crosstalk.

Some preferred embodiments of the present invention will now be described by way of example only and with reference to the accompanying drawings, in which:

Figure 1 is a schematic plan view of a conventional auto-stereoscopic display device;

Figure 2 is a schematic illustration of viewing windows provided by a conventional multiple-view display device;

Figure 3 is a schematic plan view of viewing windows produced by another conventional multiple-view directional display device;

Figure 4 is a schematic plan view of another conventional auto-stereoscopic display device;

Figure 5 illustrates a conventional dual-view apparatus installed in a motor car;

Figures 6a to 6d illustrate a known method of reducing crosstalk between images of a dual-view display;

Figures 7a to 7c illustrate a method of increasing the angles of each image and reducing crosstalk in accordance with the invention;

Figure 8 illustrates the design parameters of a colour filter parallax barrier;

Figure 9 illustrates an autostereoscopic display having a large barrier-pixel separation, and an NP3 interlacing scheme but no colour filters;

Figure 10 illustrates an autostereoscopic display having a small barrier-pixel separation and an NP1 interlacing scheme;

Figure 11 illustrates an autostereoscopic display having a large barrier-pixel separation and an NP1 interlacing scheme;

Figure 12 illustrates an autostereoscopic display having a large barrier-pixel separation and an NP3 interlacing scheme;

Figure 13 illustrates an autostereoscopic display having a large barrier-pixel separation, an NP1 interlacing scheme, and no opaque portions in the barrier;

Figure 14 illustrates a dual-view display having a large barrier-pixel separation and an NP1 interlacing scheme;

Figure 15 illustrates a dual-view display having a large barrier-pixel separation and an NP3 interlacing scheme;

Figure 16 illustrates a dual-view display having a large barrier-pixel separation, an NP1 interlacing scheme, and no opaque portions in the barrier;

Figures 17a and 17b illustrate the principle of operation of one embodiment of the invention;

Figure 18 illustrates a dual-view display having colour filters transmitting secondary colours;

Figures 19a and 19b illustrate two displays having a repeating pattern of more than three colour filters;

Figures 20a and 20b illustrate two displays having colour filters of varying widths;

Figures 21a and 21b illustrate a display having colour filters and transparent portions in the parallax barrier;

Figures 22a and 22b illustrate displays in which the order of the pixels has been changed; and

Figures 23a and 23b illustrate how one embodiment of the invention enables the barrier-display separation to be reduced.

Like reference numerals denote like components throughout the drawings.

Figure 7a illustrates in front view a dual-view display 1 according to one embodiment of the invention having an LCD array 8 of pixels and a parallax barrier 13. The pixels are arranged using the NP3 interlacing system, so that the first three pixels 27,28,29 emit red, green and blue light corresponding to image 2; the next three pixels 30,31,32 emit red, green and blue light corresponding to image 1; and the next three pixels 33,34,35 emit red, green and blue light corresponding to image 2.

The parallax barrier 13 comprises opaque regions 14 and slits 15, in a similar manner to the barriers shown in Figure 6. In each slit 15 is placed a series of colour filters 36,37,38,39. The colour filters have substantially the same spacing as the pixels, and in the embodiment shown there are four filters in each slit, coloured red, yellow, cyan and blue. The red filter transmits red light only. The yellow filter transmits red light and green light. The cyan filter transmits green light and blue light, and the blue filter transmits blue light only. In this and subsequent figures, the filters are labelled by their colour: "R" for red, "B" for blue, "G" for green, "Y" for yellow, "C" for cyan and "M" for magenta.

The pitch of the filters 36,37,38,39 within the slit is substantially the same as the pitch of the pixels. The red filter 36 is aligned with the green pixel 31 at the centre of three pixels transmitting image 1. The yellow filter 37 is aligned with the blue pixel 32 at the edge of the image 1 group. The cyan filter 38 is aligned with the red pixel 33 at the start of the adjacent image 2 group, and the blue filter 39 is aligned with the green pixel in the centre of the image 2 group.

It is apparent from Figure 7a that the range of angles 20,22 at which image 1 only is visible to the viewer has been increased by comparison with the arrangement shown in Figure 6a. In addition, the slit width is much greater than the slit width shown in Figure 6c, leading to a significant increase in brightness. Thus much greater freedom of head movement for the viewer has been obtained with a much smaller loss in the brightness of the image.

A further advantage of the arrangement of Figure 7a is apparent from Figure 7b. When the display is viewed at 90°, the filters 36,37,38,39 line up with the pixels 31,32,33,34 in such a way that none of the light from the pixels can pass through the filters. Thus, when the viewer looks at the display at 90°, he will see no light emitting from the display. This substantially reduces or even eliminates the image mixing (crosstalk) which occurs using conventional opaque / transparent parallax parries.

This behaviour is illustrated in Figure 7c. In the region 24 at the right hand of the Figure, a viewer 20 will see only image 1. In the region 25 at the left hand of the Figure, the viewer will see only image 2. In the narrow region 26 between these two regions, no light is emitted and the device will appear black to the viewer.

Figure 8 illustrates the most important design parameters for a parallax barrier including colour filters. As shown in Figure 8, the pixels are arranged so that they emit light for "left" and "right" images alternately, using the interlacing system NP1. It will be appreciated that parallax barriers including colour filters can be designed for use with any interlacing system, NP1, NP2, NP3...etc.

In Figure 8, and subsequent figures, the pixels are labelled both by which image they are part of and the colour of light emitted. For example, a pixel labelled L_B is a pixel emitting blue light for the left image. A pixel labelled R_G emits green light for the right image.

The separation between the pixels 8 and the parallax barrier 13 is labelled "d" in Figure 8. The use of a suitable arrangement of colour filters in the parallax barrier enables a wide range of different separations to be used to achieve the same angular separation between images. For example, the barrier 13 shown in Figure 14 is three times as far from the pixels 8 as the barrier shown in Figure 18, but in both cases the angular separation of the images is the same.

The width of the slit in the barrier 13 is labelled "s" in Figure 8. Figure 8 shows a slit containing only a red filter as an example only. The slit width substantially controls the angular range β over which left or right pixels can be seen. In order to obtain good head freedom this angular range needs to be large. Examples of this can be seen in Figures 15 and 16. In Figure 15, the slit widths are narrow and the pixels can only be seen over a small range of angles. In Figure 16 the slit widths are larger, and the pixels can be seen over a larger angular range.

Figure 9 illustrates a known autostereoscopic display in which the parallax barrier 13 has opaque portions 14 and transparent slits 15 but no colour filters. The interlacing system is NP3. The barrier-pixel separation is large and the width of the slit is comparable to the width of a set of three pixels (i.e. three adjacent pixels forming part of e.g. the left image). Light for the viewer's right eye 40 passes from the right pixels 30,31,32 through the slit 15. Similarly, light for the left eye 41 passes from the left pixels 27,28,29 through the slit 15.

The angular range subtended by the slit at each of the pixels 29,30,31 of the right image is shown by dotted lines. It is apparent that the viewer's left eye 41 will also be able to

see some light from at least one of the red pixels 30 of the right image. The crosstalk between the images is therefore very large and, although the brightness of each image is high, the viewer will be able to see colour artefacts and has very poor freedom of head movement.

Figure 10 shows a similar autostereoscopic display, although in this case the pixels 8 are arranged using the NP1 interlacing system and the barrier-pixel separation is small. The width of each slit 15 is similar to the width of each individual pixel. The angular range subtended by the slit at each of the right pixels 48,50,52 is again shown by dotted lines. This time there will be no crosstalk or colour artefacts, but poor brightness and head freedom.

Figure 11 demonstrates the use of colour filters in an autostereoscopic display. The barrier-pixel separation is large and the slits are again comparable with the pixel width, arranged for NP1 interlacing. The display exhibits good head freedom and brightness, and a lack of colour artefacts, compared to a similar display with empty slits in place of colour filters.

Figure 12 demonstrates a similar arrangement to Figure 9, but this time red, green and blue colour filters 55,56,57 have been inserted into the slit 15. This reduces the occurrence of colour artefacts.

Figure 13 illustrates an autostereoscopic display in which the arrangement of colour filters has enabled the complete removal of opaque regions from the parallax barrier 13. This enables good head freedom and good brightness, without the problem of colour artefacts.

Figures 14, 15 and 16 are similar in design to the displays shown in Figures 11, 12, and 13, except that in each case the barrier has been moved closer to the pixels. This increases the angular separation between the two images and enables displays of this type to be used as dual view displays ins addition to autostereoscopic displays. These

displays all allow good head freedom and have a black central "window" when viewed at 90° to the display. "Left" and "right" in Figures 14-16 refer to left and right viewing positions rather than the left or right eyes of a viewer.

The black central window is particularly important for dual-view displays. The central region of an autostereoscopic display will fall between a user's eyes and thus may not be seen. So crosstalk in this region may not matter. However, returning to the example shown in Figure 5 of a dual-view display in a car, a viewer located centrally (in the back seat, for example), would view the display 18 at 90°. It is therefore important that such a display should have a black central region rather than a region of crosstalk.

All of the displays shown in Figures 11 to 13 and 14 to 16 use colour filters each allowing a single primary colour to pass. By using filters allowing more than one primary colour to pass, greater flexibility in the design of the parallax barrier is obtained.

Figure 17a illustrates the requirements for a barrier 13 having large slits and a large angle subtended from each colour filter at each pixel. The display uses NP3 interlacing and demonstrates the regions 58,59,60 which must allow red, green and blue light respectively to pass. In order to get good angular variation, these regions overlap each other. It will be noted that the region 58 transmitting red light is much larger than the red pixels 27, 30 whose light will pass through it. These large regions transmitting light from each pixel greatly increase the brightness and head freedom for the viewer.

Figure 17b shows how such a barrier can be manufactured in practice. Where both green and red light must be transmitted, a yellow filter 61 is used. Where green and blue light must be transmitted, a cyan filter 62 is used. In other words, some of the colour filters may be secondary rather than primary colours. It will be noted that the width of each filter is substantially the same as the width of the pixels, but as shown in Figure 17a, the region 58,59,60 transmitting each primary colour is much larger than the

width of the corresponding pixel. The display exhibits good brightness, a good angular range for each image, and no crosstalk.

Figure 18 illustrates a display similar to that shown in Figure 10, in which secondary colour filters have been inserted into the slits 15. The use of colour filters in such a barrier removes crosstalk when the barrier is viewed from oblique angles – i.e. outside the usual left and right viewing regions.

Figure 19a illustrates an NP3 display in which the slits have been enlarged even further. The display could be used as an autostereoscopic display or a dual-view display. The colour filters have been "rearranged" so that they no longer follow the simple red, green blue pattern – there are five filters 63-67 in each slit 15. Figure 19b illustrates a similar arrangement using only primary colour filters 63-67, but which still has five in each slot. In figure 19b the order of the pixels has been changed as well: the order of the left pixels is a mirror image of the order of the right pixels.

Rearranging the colour filters allows the barrier to be closer to the panel. It also allows the green colour filter (as shown in Figure 19b) to be in the centre of the slit. If the green colour filter leaks some red and blue the effects are insignificant. This helps reduce crosstalk problems caused by leakage of the colour filters.

Figure 20a illustrates a further possible embodiment of the invention. In this embodiment the filters are not of uniform width. Each slit 15 contains a secondary colour filter 68 flanked on either side by a narrower primary colour filter 69. This enables further control over the direction of light transmitted.

Figure 20b is a similar design to Figure 20a, but the opaque regions 14 have been removed. The primary colour filters each side of the opaque region expand to fill this region. The angular range of each pixel, and thus the freedom of head movement, is now very large, but there is still very little crosstalk and high brightness.

Figure 21 illustrates a further embodiment of the invention. Figure 21a shoes regions 58',59',60', like regions 58-60 of Figure 17a, in which red, green and blue light respectively should pass. At the centre of the slit all three regions overlap, so all light of all three primary colours should be transmitted. A barrier 13 putting this into practice is shown in Figure 21b. The central region 70 is substantially transparent so as to allow light of all three primary colours to pass, and is flanked by secondary colour filters 71, 72.

Figure 22 provides a further example of possible arrangements in accordance with the invention. Both use NP3 interlacing, and in both cases the pixel order is different for left and right images.

Figure 23 illustrates how the use of secondary colour filters can enable the barrier 13 to be brought closer to the pixels 8 to achieve the same angular separation between images. In Figure 23a the filters are primary colour filters and the barrier-pixel separation is large. In Figure 23b, secondary colour filters and a transparent portion 70 are used, enabling the barrier to be placed much closer to the pixels. In effect, the region passing each primary colour is larger in Figure 23a than in Figure 23b.

It will also be appreciated that the arrangement of Figure 23b provides a much larger degree of head freedom than that of Figure 23a. This is because in Figure 23a each colour filter transmitting a single primary colour is comparable in width to a pixel. In Figure 23b, the region transmitting a single primary colour is much larger – more than twice the width of a pixel.

The present invention provides a multiple view directional display comprising a display device and a parallax optic having an array of colour filters. It will be appreciated by the person skilled in the art that various modifications may be made to the above embodiments without departing from the scope of the present invention.

For example, the embodiments described above are all illustrated with reference to a multiple view display of the type shown in Figure 1 having a parallax barrier 5 in front of the spatial light modulator 4. It will be appreciated that the invention could equally well apply to a display of the type shown in Figure 4, where the parallax barrier 5 is located between the backlight 11 and the SLM 4. As a further alternative, the parallax barrier aperture array 13 could be removed altogether, with the backlight itself being arranged to emit light of different colours. For example, the backlight could comprise an array of LEDs, some or all of which emit light of secondary colours.

In a further refinement, the colour filters or backlight colour array could be switchable. This would enable the location of the left and right viewing windows to be altered. This could be useful, for example, in an autostereoscopic display. If the viewer's head is moved, the display could be reconfigured dynamically so that the left and right images are still directed towards his eyes. Alternatively, for example by switching all the colour filters and opaque regions in the parallax barrier so that they are fully transparent, a dual-view display could be reconfigured for use as a single-view display.

CLAIMS:

1. A multiple-view directional display, comprising: an image display device comprising a set of picture elements, and a parallax optic comprising an array of colour filters.

2. A display as claimed in claim 1, in which each colour filter is aligned with a respective set of the picture elements.

3. A display as claimed in claim 1 or 2, wherein the colour filters are arranged in apertures in the parallax optic.

4. A display as claimed in claim 1, 2 or 3, wherein each picture element is arranged to emit light of a primary colour, and wherein at least one of the colour filters is arranged to transmit light of more than one primary colour.

5. A display as claimed in any preceding claim, wherein the parallax optic comprises at least one substantially transparent region for transmitting light of all three primary colours.

6. A display as claimed in claim 4, wherein all of the colour filters are of a secondary colour arranged to transmit two primary colours.

7. A display as claimed in claim 6, wherein the picture elements show portions of two images alternately.

8. A display as claimed in any preceding claim, wherein the colour filters are arranged in a periodically repeating pattern.

9. A display as claimed in claim 8, wherein the picture elements are arranged to emit coloured light in a periodically repeating pattern, and the pattern of the colour filters and picture elements is different.

10. A display as claimed in claim 8 or 9, wherein one period of the colour filter pattern includes: a first filter arranged to transmit light of only a first primary colour; a second filter arranged to transmit light of the first primary colour and a second primary colour; a third filter arranged to transmit light of the second primary colour and a third primary colour; and a fourth filter arranged to transmit light of only the third primary colour.

11. A display as claimed in claim 8 or 9, wherein one period of the colour filter pattern includes: a first filter arranged to transmit light of only a first primary colour; a second filter arranged to transmit light of only a second primary colour; a third filter arranged to transmit light of the first primary colour and a third primary colour; a fourth filter arranged to transmit light of the second primary colour; and a fifth filter arranged to transmit light of only the third primary colour.

12. A display as claimed in claim 8 or 9, wherein one period of the colour filter pattern includes: a first filter arranged to transmit light of only a first primary colour; a second filter arranged to transmit light of only a second primary colour; a third filter arranged to transmit light of only a third primary colour; a fourth filter arranged to transmit light of the second primary colour; and a fifth filter arranged to transmit light of the first primary colour.

13. A display as claimed in claim 12, wherein the picture element pattern includes elements arranged to emit primary colours in the order first, second, third, third, second, first.

14. A display as claimed in claim 12 or 13, wherein the third primary colour is green.

15. A display as claimed in claim 8 or 9, wherein one period of the colour filter pattern includes: a first filter arranged to transmit light of a first primary colour and a second primary colour; a second filter arranged to transmit light of only a third primary colour; and a third filter arranged to transmit light of the first and second primary colours.

16. A display as claimed in claim 15, wherein the picture element pattern includes elements arranged to emit primary colours in the order first, third, second, second, third, first.

17. A display as claimed in claim 8 or 9, wherein one period of the colour filter pattern includes: a first filter arranged to transmit light of only a first primary colour; a second filter arranged to transmit light of a first primary colour and a second primary colour; a third filter arranged to transmit light of the second primary colour and a third primary colour; a fourth filter arranged to transmit light of the third and first primary colours; and a fifth filter arranged to transmit light only of the first primary colour.

18. A display as claimed in any of claims 10 to 17, wherein the picture elements are arranged in groups of three so that three adjacent picture elements show the same image.

19. A display as claimed in any of claims 10 to 18, wherein the width of each colour filter is substantially the same as the spacing of the picture elements.

20. A display as claimed in any of claims 10 to 19, wherein one period of the colour filter pattern further includes an opaque mask.

21. A display as claimed in claim 8 or 9, wherein the colour filters are of varying width.

22. A display as claimed in claim 8, 9 or 21, wherein one period of the colour filter pattern includes: a first filter arranged to transmit light of only a first primary colour; a second filter arranged to transmit light of the first primary colour and a second primary colour; a third filter arranged to transmit light of only the second primary colour; a first opaque mask; a fourth filter arranged to transmit light of only the second primary colour; a fifth filter arranged to transmit light of the second primary colour and a third primary colour; a sixth filter arranged to transmit light of only the third primary colour; a second opaque mask; a seventh filter arranged to transmit light of only the third primary colour; an eighth filter arranged to transmit light of the third and first primary colours; a ninth filter arranged to transmit light of only the first primary colour; and a third opaque mask.

23. A display as claimed in claim 22, wherein the second, fifth and eighth filters are wider than the first, third, fourth, sixth, seventh and ninth filters.

24. A display as claimed in claim 8, 9 or 21, wherein one period of the colour filter pattern includes: a first filter arranged to transmit light of only a first primary colour; a second filter arranged to transmit light of the first primary colour and a second primary colour; a third filter arranged to transmit light of only the second primary colour; a fourth filter arranged to transmit light of the second primary colour and a third primary colour; a fifth filter arranged to transmit light of only the third primary colour; and a sixth filter arranged to transmit light of the third and first primary colours.

25. A display as claimed in claim 24, wherein the first, third and fifth filters are wider than the second, fourth and sixth filters.

26. A display as claimed in claim 24 or 25, wherein the parallax element does not comprise opaque portions.

27. A display as claimed in claim 8, 9 or 21, wherein one period of the colour filter pattern includes: a first filter arranged to transmit light of only a first primary colour; a

second filter arranged to transmit light of the first primary colour and a second primary colour; a transparent portion arranged to transmit light of all three primary colours; a third filter arranged to transmit light of the second primary colour and a third primary colour; and a fourth filter arranged to transmit light of only the third primary colour.

28. A display as claimed in claim 27, wherein the transparent portion is narrower than the colour filters.

29. A display as claimed in any of claims 1 to 7, wherein the colour filters are arranged in a periodically repeating pattern, and wherein the number of colour filters in a single period of the pattern is greater than three.

30. A display as claimed in any of claims 1 to 7, wherein the picture elements are arranged in a periodically repeating pattern, and wherein the number of picture elements in a single period of the pattern is greater than three.

31. A display as claimed in any of claims 1 to 7, wherein the width of the colour filters varies.

32. A display as claimed in any preceding claim, wherein some or all of the colour filters are switchable.

33. A display as claimed in any preceding claim, which display is a dual-view display.

34. A dual-view display as claimed in claim 33, wherein the colour filters are arranged such that there is a region at 90° to the display which appears dark to the viewer.

35. A multiple-view directional display, comprising an image display device comprising a set of picture elements illuminated by an array of light sources, at least one of which emits light of a secondary colour.

36. A parallax optic comprising an array of colour filters, at least one of which transmits more than one primary colour.

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Application No: GB 0320364.3
Claims searched: 1

Examiner: Matthew Males
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Patents Act 1977 : Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance	
X	1 - 5, 8 - 10, 19 at least	US 20030052836 A1	MATSUMOTO et al - whole document but see Fig 1 & pg 3, paras [0068] - [0071], for example.
X	1 - 3 at least	US 6392690 B1	FUJII et al - whole document but see abstract.
X	1 at least	EP 1329759 A1	JAPAN SCIENCE AND TECHNOLOGY CORPORATION - whole document but see abstract; col 12, lines 11 - 25 & Fig 9, for example.

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
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Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC^{W}:

G2J, H4F

Worldwide search of patent documents classified in the following areas of the IPC^{7}:

G02B, H04N

The following online and other databases have been used in the preparation of this search report:

WPI, EPODOC, JAPIO